HP 436A

OPERATING INFORMATION

HP 436A POWER METER

DUPLICATE OF SECTIONS 1 THRU 3 OF YOUR OPERATING AND SERVICE MANUAL

KEEP WITH INSTRUMENT

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HEWLETT PACKARD

HP 436A

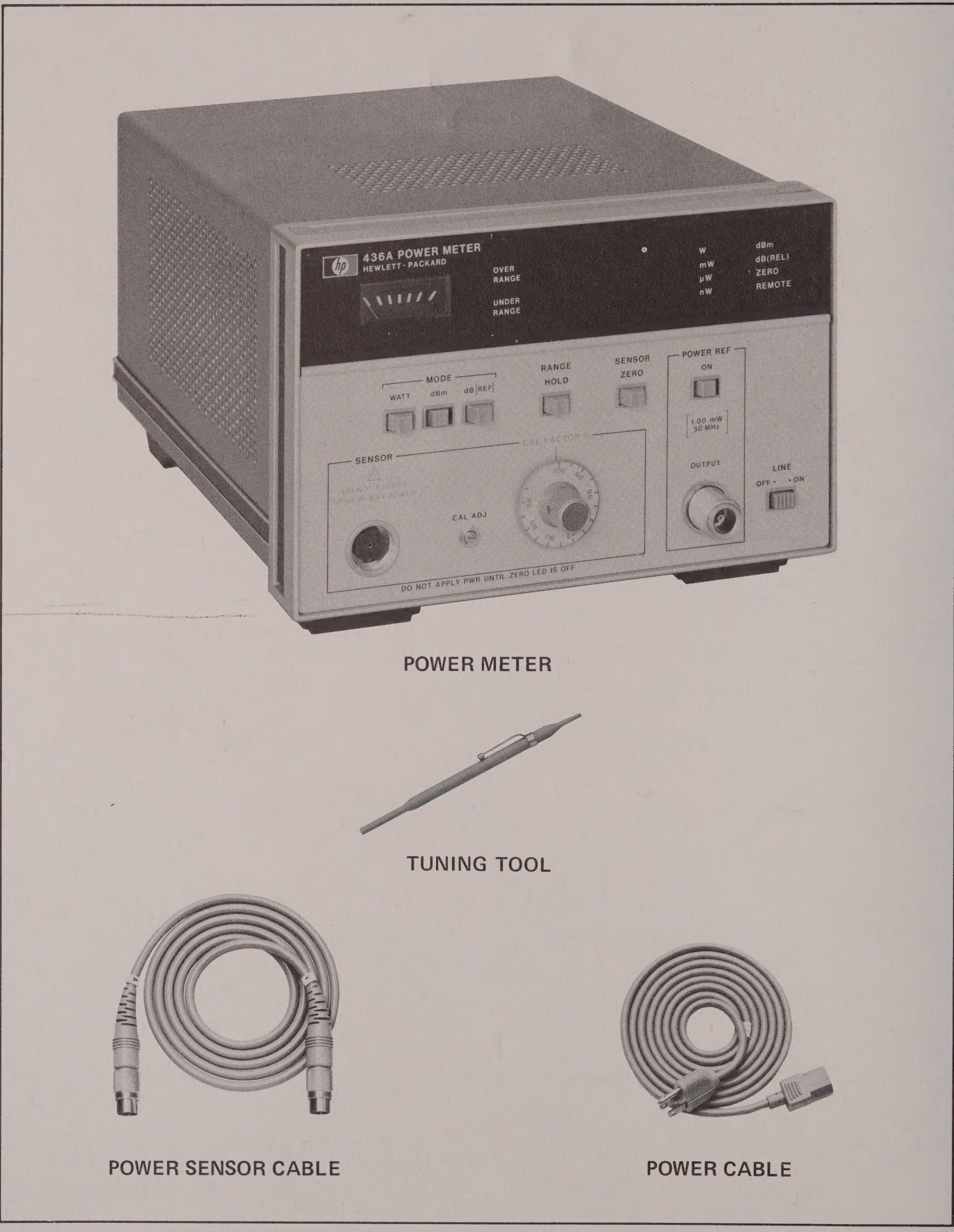


Figure 1-1. HP Model 436A Power Meter and Accessories Supplied

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION

1-2. This manual provides information pertaining to the installation, operation, testing, adjustment and maintenance of the HP Model 436A Power Meter.

1-3. Figure 1-1 shows the Power Meter with accessories supplied.

1-4. Packaged with this manual is an Operating Information Supplement. This is simply a copy of the first three sections of this manual. This supplement should be kept with the instrument for use by the operator. Additional copies of the Operating Information Supplement may be ordered through your nearest Hewlett-Packard office. The part numbers are listed on the title page of this manual.

1-5. On the title page of this manual, below the manual part number, is a "Microfiche" part number. This number may be used to order 4x6-inch microfilm transparencies of the manual. The microfiche package also includes the latest Manual Changes supplement as well as all pertinent Service Notes.

1-6. SPECIFICATIONS

1-7. Instrument specifications are listed in Table 1-1. These specifications are the performance standards or limits against which the instrument may be tested.

1-8. INSTRUMENTS COVERED BY MANUAL

1-9. Power Meter Options 003, 004, and 022 are documented in this manual. The differences are noted in the appropriate location such as OPTIONS in Section I, the Replaceable Parts List, and the schematic diagrams.

1-10. This instrument has a two-part serial number. The first four digits and the letter comprise the serial number prefix. The last five digits form the sequential suffix that is unique to each instrument. The contents of this manual apply directly to instruments having the same serial number prefix(es) as listed under SERIAL NUMBERS on the title page.

1-11. An instrument manufactured after the printing of this manual may have a serial prefix that is not listed on the title page. This unlisted serial prefix indicates that the instrument is different from those documented in this manual. The manual for this instrument is supplied with a yellow Manual Changes supplement that contains change information that documents the differences.

1-12. In addition to change information, the supplement may contain information for correcting errors in the manual. To keep this manual as current and accurate as possible, Hewlett-Packard recommends that you periodically request the latest Manual Changes supplement. The supplement for this manual is keyed to the manual's print date and part number, both of which appear on the title page. Complimentary copies of the supplement are available from Hewlett-Packard.

1-13. For information concerning a serial number prefix not listed on the title page or in the Manual Changes supplement, contact your nearest Hewlett-Packard office.

1-14. DESCRIPTION

1-15. The Power Meter is a precision digital-readout instrument capable of automatic and manual measurement of RF and Microwave power levels. It is designed for interconnection with a compatible Power Sensor (refer to Table 1-1, Specifications) to form a complete power measurement system. The frequency and power range of the system are determined by the particular Power Sensor selected for use. With the Power Sensors available, the overall frequency range of the system is 100 kHz to 18 GHz, and the overall power range is −70 to +35 dBm.

1-16. Significant operating features of the Power Meter are as follows:

- **Digital Display:** The display is a four-digit, seven-segment LED, plus a sign when in the dBm or dB (REL) mode. It also has under- and

Table 1-1. Specifications

SPECIFICATIONS

Frequency Range:
100 kHz to 26.5 GHz (depending on power sensor used).

Power Range:
(display calibrated in watts, dBm, and dB relative to reference power level).

With 8481A, 8482A, or 8483A sensors: 50 dB with 5 full scale ranges of −20, −10, 0, 10, and 20 dBm (10 μW to 100 mW).

With 8481B or 8482B sensors: HP 8481B is 44 dB (1 mW to 25W) at 0 to 35°C and HP 8482B is 43 dB (1 mW to 20W) at 35°C to 55°C with 5 ranges of 10, 20, 30, 40 and 43 or 44 dBm.

With 8481H or 8482H sensors: 45 dB with 5 ranges of 0, 10, 20, 30 and 35 dBm (1 mW to 3W).

With 8484A sensor: 50 dB with 5 full scale ranges of −60, −50, −40, −30, and −20 dBm (1 nW to 10 μW).

Accuracy:

Instrumentation[1]**:**
Watt mode: ±0.5%.
dBm mode: ±0.02 dB ±0.001 dB/°C.
dB [REL] mode[2]: ±0.02 dB ±0.001 dB/°C.

Zero: Automatic, operated by front panel switch.

Zero set: ±0.5% of full scale on most sensitive range. typical, ±1 count on other ranges.

Zero carry over: ±0.2% of full scale when zeroed on the most sensitive range.

Noise (typical, at constant temperature, peak change over any one-minute interval): 20 pW (8484A); 40 nW (8481A, 8482A, 8483A); 4 μW (8481H, 8482H).

Drift (1 hour, typical, at constant temperature after 24-hour warm-up); 20 pW (8484A); 10 nW (8481A, 8482A, 8483A); 1.0 μW (8481H, 8482H).

Power Reference: Internal 50 MHz oscillator with Type N Female connector on front panel (or rear panel, Option 003 only).

Power output: 1.00 mW.
Factory set to ±0.7%, traceable to the National Bureau of Standards.
Accuracy: ±1.2% worst case (±0.9% rss) for one year (0°C to 55°C).

Response Time:
(0 to 99% of reading, five time constants)

Range 1 (most sensitive)	<10 seconds.
Range 2	<1 second
Range 3—5	<100 milliseconds.

(Typical, measured at recorder output).

Cal Factor:
16-position switch normalizes meter reading to account for calibration factor or effective efficiency. Range 85% to 100% in 1% steps.

Cal Adjustment:
Front panel adjustment provides capability to adjust gain of meter to match power sensor in use.

Recorder Output:
Proportional to indicated power with 1 volt corresponding to full scale and 0.316 volts to −5 dB; 1 kΩ output impedance, BNC connector.

RF Blanking Output:
Open collector TTL; low corresponds to blanking when auto-zero mode is engaged.

Display:
Digital display with four digits, 20% over-range capability on all ranges. Also, uncalibrated analog peaking meter to see fast changes.

Power Consumption:
100V ± 10%, 48 to 66 Hz and 360 to 440 Hz.
120V +5%, −10%, 48 to 66 Hz and 360 to 440 Hz.
220 or 240V +5%, −10% 48 to 66 Hz.
Typically less than 24 watts (<25 watts for Opt. 022), 60 V·A maximum.

Dimensions:
134 mm High (5-1/4 inches).
213 mm Wide (8-3/8 inches).
279 mm Deep (11 inches).

Net Weight: 4.5 kg (10 lbs).

[1]Includes sensor non-linearity. Add +2, −4% on top range when using the 8481A, 8482A, or 8483A power sensors.

[2]Specifications are for within range measurements. For range-to-range accuracy add the range uncertainties.

DESCRIPTION (cont'd)

overrange indicators. There is a 20 percent overrange capability in all ranges. Large 10 mm (0.375 inch) digits are easy to see even in a high glare environment.

- **Auxiliary Meter:** Complements the digital display by showing fast changes in power level. Ideal for "peaking" transmitter output or other variable power devices.

- **Choice of Display in Watts, dBm or dB:** Absolute power can be read out in watts or dBm. Relative power measurements are made possibile with the dB [REF] switch. Pressing this switch zeros the display for any applied input power and any deviation from this reference is shown in dB with a resolution of ±0.01 dB. This capability is particularly useful in frequency response testing.

- **Power Units and Mode Annunciator:** The units annunciator provides error-free display interpretation by indicating appropriate power units in the watt mode. The mode annunciator indicates the mode of operation: dBm, dB (REL), ZERO or REMOTE.

- **Completely Autoranging:** The Power Meter automatically switches through its 5 ranges to provide completely "hands off" operation. The RANGE HOLD switch locks the Power Meter in one of its ranges when autoranging is not desired.

- **Automatic Sensor Recognition:** The Power Meter continually decodes the sensitivity of the Power Sensor to which it is connected. This information is then used to automatically control the digital display decimal point location and, when WATT MODE operation is selected, to light the appropriate power units annunciator.

- **Auto Zero:** Zeroing the meter is accomplished by merely depressing the SENSOR ZERO switch and waiting until the display shows all zeros before releasing it. The meter is ready to make measurements as soon as the zero light in the mode annunciator goes off.

- **RF Blanking Output:** Open collector TTL; low corresponds to blanking when the sensor zero is engaged, May be used to remove the RF input signal connected to the power sensor.

- **Calibration Accuracy:** A 1.00 mW, 50 MHz reference output is available at the front panel for calibrating the Power Meter and the Power Sensor as a system. Calibration is accomplished using the CAL ADJ and CAL FACTOR % controls. The CAL ADJ control compensates for slight differences in sensitivity associated with a particular type of Power Sensor and the CAL FACTOR % control compensates for mismatch losses and effective efficiency over the frequency range of the Power Sensor.

- **Recorder Output:** Provides a linear output with respect to the input power level. For each range, a +1.00 Vdc output corresponds to a full scale input power level. Refer to Table 1-1, Specifications, for the full-scale range values associated with the various types of Power Sensors available.

1-17. The Hewlett-Packard Interface Bus (HP-IB) Option 022 allows full remote control operation of all the power meter functions (CAL FACTOR can be programmed to either 100% or the CAL FACTOR which has been manually set on the front panel). This option may be added by the user at a later time as his requirements grow.

1-18. OPTIONS

1-19. Input-Output Options

1-20. Option 003. A rear panel POWER REF OUTPUT connector replaces the standard front panel connector.

1-21. Option 004. The 1.5 metre (5 ft.) power sensor cable is not shipped with the power meter.

1-22. Remote Control Options

1-23. Option 022 adds remote interface capability to the Power Meter. Option 022 is compatible with the Hewlett-Packard Interface Bus (AH1, C0, DC2, DT1, L2, LE0, PP0, RL2, SH1, SR0, T3, TE0).

1-24. Option 022 may be ordered in kit form under HP part number 00436-60035. The kit contains a control assembly printed-circuit board, an input/output assembly printed circuit board, and a data cable for interconnection.

1-25. ACCESSORIES SUPPLIED

1-26. The accessories supplied with the Power Meter are shown in Figure 1-1.

a. The 1.5 metre (5 ft.) Power Sensor Cable, HP 11730A, is used to couple the Power Sensor to the Power Meter. Order option 004 to delete the standard 1.5 metre cable.

b. The line power cable may be supplied in one of four configurations. Refer to the paragraph entitled Power Cables in Section II.

c. An alignment tool for adjusting the CAL ADJ front panel control (HP Part No. 8710-0630).

1-27. EQUIPMENT REQUIRED BUT NOT SUPPLIED

1-28. To form a complete RF power measurement system, a Power Sensor such as the HP Model 8481A must be connected to the Power Meter via the Power Sensor cable.

1-29. EQUIPMENT AVAILABLE

1-30. The HP Model 11683A Range Calibrator is recommended for performance testing, adjusting, and troubleshooting the Power Meter. The Power Meter's range-to-range accuracy and auto-zero operation can easily be verified with the Calibrator. It also has the capability of supplying a full-scale test signal for each range.

1-31. Two extender boards (HP Part Numbers 5060-0258, and 5060-0630; 24 and 44 pins respectively) enable the Power Meter printed circuit assemblies to be accessed for service. Rubber bumpers (HP Part No. 0403-0015) should be installed on the extender boards to prevent the boards from touching.

1-32. The following table lists the cable accessories and their lengths that are available for use with the Power Meter. Order option 004 if the standard 1.5 metre cable is not desired with a cable accessory.

Cable Accessory	Cable Length
HP 11730B	3.0 m (10 ft)
HP 11730C	6.1 m (20 ft)
HP 11730D	15.2 m (50 ft)
HP 11730E	30.5 m (100 ft)
HP 11730F	61.0 m (200 ft)

1-33 RECOMMENDED TEST EQUIPMENT

1-34. The test equipment shown in Table 1-2 is recommended for use during performance testing, adjustments, and troubleshooting. To ensure optimum performance of the Power Meter, the specifications of a substitute instrument must equal or exceed the critical specifications shown in the table.

1-35 SAFETY CONSIDERATIONS

1-36. The Power Meter is a Safety Class I instrument. This instrument has been designed according to international safety standards.

1-37. This operating and service manual contains information, cautions, and warnings which must be followed by the user to ensure safe operation and to retain the instrument in safe condition.

Table 1-2. Recommended Test Equipment

Instrument Type	Critical Specifications	Suggested Model	Use *
Range Calibrator	Chopped dc output for each range referenced to 1 mW range	HP 11683A	P,A,T
Digital Voltmeter	Function: DC, resistance Range Resistance: 200 ohms Vdc: 100 mVdc, 1000 mVdc, 10 Vdc, 100 Vdc 10MΩ input impedance 6-digit resolution (±0.05% of reading, ±0.02% of range)	HP 3456A	P,A,T
Power Meter	Range: 1 mW Transfer Accuracy (input -to-output): 0.2%	HP 432A	P, A
Thermistor Mount	SWR: 1.05, 50 MHz Accuracy: ±0.5% at 50 MHz	HP 478A-H75** or HP 478A-H76***	P, A
Counter	Frequency Range: 220 Hz, 50 MHz Sensitivity: 100 mVrms Accuracy: 0.01%	HP 5315A	A
Oscilloscope	Bandwidth: dc to 50 MHz Vertical Sensitivity: 0.2V/division Horizontal Sensitivity: 1 ms/division	HP 180C/ 1801A/1821A	T
Logic Analyzer	Clock Input: 60 kHz Trigger Word: 8 Bits Bit Input: TTL Display Word: 8 Bits	HP 1600A	T

*P = Performance Tests; A = Adjustments; T = Troubleshooting

**HP 478A-H75 must be calibrated at the National Bureau of Standards (NBS) for this accuracy.

***HP 478A-H76 includes HP standards lab calibration to ± 0.58% at 50 MHz (traceable to NBS).

SECTION II
INSTALLATION

2-1. INTRODUCTION

2-2. This section provides all information necessary to install the Power Meter. Covered in the section are initial inspection, power requirements, line voltage selection, interconnection, circuit options, mounting, storage, and repackaging for shipment.

2-3. INITIAL INSPECTION

2-4. Inspect the shipping container for damage. If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the instrument has been checked mechanically and electrically. The contents of the shipment should be as shown in Figure 1-1. Procedures for checking electrical performance are given in Section IV. If the contents are incomplete, if there is mechanical damage or defect, or if the instrument does not pass the electrical performance test, notify the nearest Hewlett-Packard office. If the shipping container is damaged, or the cushioning material shows signs of stress, notify the carrier as well as the Hewlett-Packard office. Keep the shipping materials for the carrier's inspection.

2-5. PREPARATION FOR USE

2-6. Power Requirements

2-7. The Power Meter requires a power source of 100, 120, 220, or 240 Vac, +5%, −10%, 48 to 440 Hz single phase. Power consumption is approximately 20 watts.

WARNING

If this instrument is to be energized via an autotransformer for voltage reduction, make sure the common terminal is connected to the earthed pole of the power source.

2-8. Line Voltage and Fuse Selection

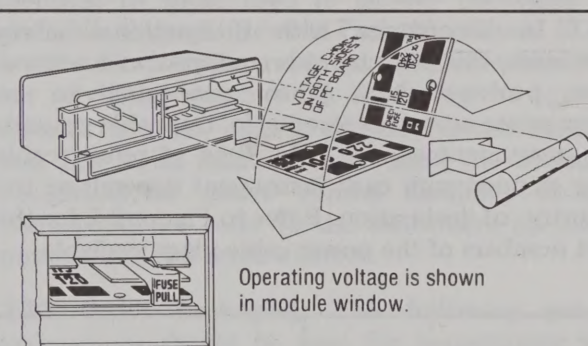
CAUTION

BEFORE PLUGGING THIS INSTRUMENT into the Mains (line) voltage, be sure the correct voltage and fuse have been selected.

2-9. A rear panel, line power module permits operation from 100, 120, 220, or 240 Vac. The number visible in the window (located on the module) indicates the nominal line voltage to which the instrument must be connected. Verify that the line voltage selection card and the fuse are matched to the power source. Refer to Figure 2-1, Line Voltage and Fuse Selection. Table 2-1 lists the ratings and HP part numbers for the replaceable fuses.

WARNING

For protection against fire hazard, the line fuse for 220/240V operation should only be a 250V slow blow fuse with the correct current rating.



SELECTION OF OPERATING VOLTAGE

1. Open cover door, pull the FUSE PULL lever and rotate to left. Remove the fuse.
2. Remove the Line Voltage Selection Card. Position the card so the line voltage appears at top-left corner. Push the card firmly into the slot.
3. Rotate the FUSE PULL lever to its normal position. Insert a fuse of the correct value in the holder. Close the cover door.

WARNING

To avoid the possibility of hazardous electrical shock, do not operate this instrument at line voltages greater than 126.5 Vac with line frequencies greater than 66 Hz (leakage currents at these line settings may exceed 3.5 mA).

Figure 2-1. Line Voltage and Fuse Selection

Table 2-1. Line Fuse Ratings and Part Numbers

Line Voltage	Rating	Part Number
100/120V 220/240V	.75A, 250V .375A, 250V, SLO-BLO	2110-0063 2110-0421

2-10. Power Cable

WARNINGS

BEFORE SWITCHING ON THIS INSTRUMENT, the protective earth terminals of this instrument must be connected to the protective conductor of the (mains) power cord. The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action must not be negated by the use of an extension cord (power cable) without a protective conductor (grounding).

2-11. In accordance with international safety standards, this instrument is equipped with a three-wire power cable. When connected to an appropriate ac power receptacle, this cable grounds the instrument cabinet. The type of power cable plug shipped with each instrument depends on the country of destination. Refer to Figure 2-2 for the part numbers of the power cable plugs available.

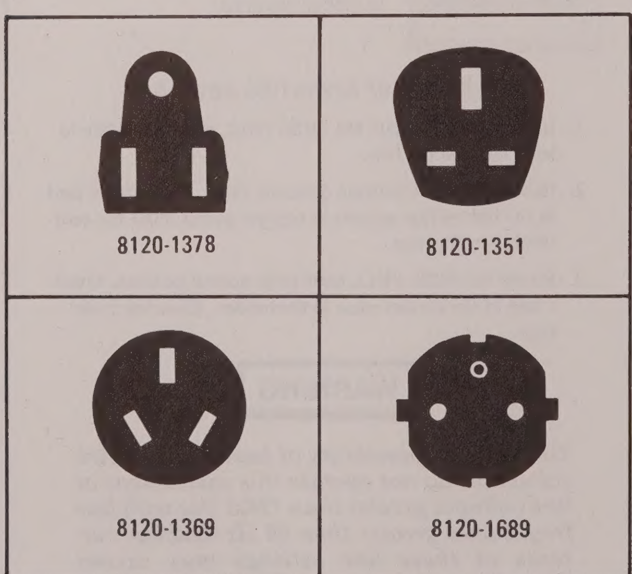


Figure 2-2. Power Cable and Mains Plug Part Numbers

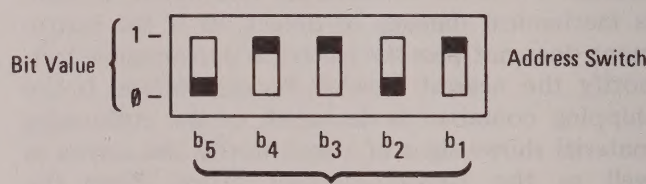
2-12. ADDRESS SELECTION

WARNINGS

This task should be performed only by service trained persons who are aware of the potential shock hazard of working on an instrument with protective covers removed.

To avoid hazardous electrical shock, the line (mains) power cable should be disconnected before attempting to change the HP-IB address.

Look up the address code in Table 2-3. Read the binary equivalent of the code. Set the five least significant bits of the code on the address switch as shown below. (The address switch A6S1, is on the HP-IB Control Assembly.)



5 least significant bits of the address code read from Table 2-3.

The switch is shown set for Talk address "M" (1001101) and Listen address "—" (0101101).

2-13. Circuit Options

2-14. A jumper option is available for selecting a filtered or unfiltered dc RECORDER OUTPUT. Table 2-2 lists the factory installed jumper connections and indicates how they may be reconnected to select the option.

2-15. Interconnections

2-16. Power Sensor. For proper system operation, the Power Sensor must be connected to the Power Meter using either the Power Sensor cable supplied with the Power Meter or any of the optional Power Sensor cables specified in Section I. Each of these cables employs a sensitivity line to enable the Power Meter to determine the operating range of the Power Sensor and thus, the true value of the input signal. For example, the 8481A and

8481H Power Sensors provide identical full scale outputs in response to input signal levels of 100 milliwatts and 3 watts, respectively. The difference in their sensitivity codes is detected by the Power Meter, however, and the Power Meter digital readout is automatically configured to indicate the appropriate value.

2-17. Hewlett-Packard Interface Bus Option 022. Interconnection data for Hewlett-Packard Interface Bus Option 022 is provided in Figure 2-3. Power Meter programming and output data format is described in Section III, Operation. HP-IB address selection is explained in Table 2-3.

2-18. Mating Connectors

2-19. Interface Connector. The interface mating connector for Option 022 is indicated in Figure 2-3.

2-20. Coaxial Connectors. Coaxial mating connectors used with the Power Meter should be US MIL-C-39012-compatible type N male or 50-ohm BNC male.

2-21. Operating Environment

2-22. The operating environment should be within the following limitations:

Temperature . . . . 0°C to +55°C
Humidity . . . . <95% relative
Altitude . . . . <4570 m (15,000 ft)

2-23. Bench Operation

2-24. The instrument cabinet has plastic feet and a fold-away tilt stand for convenience in bench operation. (The plastic feet are shaped to ensure self-aligning of the instruments when stacked.) The tilt stand raises the front of the instrument for easier viewing of the control panel.

2-25. Rack Mounting

2-26. Instruments that are narrower than full rack width may be rack mounted using Hewlett-Packard sub-module cabinets. If it is desired to rack mount one Power Meter by itself, order half-module kit, HP Part Number 5061-0057. If it is desired to rack mount two Power Meters side by side, order the following items:

a. Rack Mounting Flange Kit—(For instruments without handles) HP Part Number 5061-0077.

b. Rack Mounting Flange Kit—(For instruments with handles) HP Part Number 5061-2071.

c. Lock Link Kit—Kit consists of lock hardware and screws for joining instrument cabinets in several different configurations. Enough horizontal links (12 front, 6 rear) for three side-by-side joints (up to 4 instruments), and enough vertical links (4 front, 4 rear) to form two over/under joints (up to 3 instruments) HP Part Number 5061-0094.

2-27. In addition to the rack mounting hardware, a front handle assembly (two provided) is also available for the Power Meter. The part number is HP 5061-0089.

2-28. STORAGE AND SHIPMENT

2-29. Environment

2-30. The instrument should be stored in a clean dry environment. The following environmental limitations apply to both storage and shipment:

Temperature . . . . —40°C to +75°C
Humidity . . . . <95% relative
Altitude . . . . <7620 m (25,000 ft)

2-31. Packaging

2-32. Original Packaging. Containers and materials identical to those used in factory packaging are available through Hewlett-Packard offices. If the instrument is being returned to Hewlett-Packard for servicing, attach a tag indicating the type of service required, return address, model number, and full serial number. Also mark the container FRAGILE to assure careful handling. In any correspondence refer to the instrument by model number and full serial number.

2-33. Other Packaging. The following general instructions should be used for re-packaging with commercially available materials:

a. Wrap the instrument in heavy paper or plastic. (If shipping to a Hewlett-Packard office or service center, attach a tag indicating the service required, return address, model number, and full serial number.)

b. Use a strong shipping container. A double-wall carton made of 275-lb test material is adequate.

c. Use enough shock-absorbing material (3 to 4-inch layer) around all sides of instrument to provide firm cushion and prevent movement in the container. Protect the control panel with cardboard.

d. Seal the shipping container securely.

e. Mark the shipping container FRAGILE to assure careful handling.

Table 2-2. Circuit Options

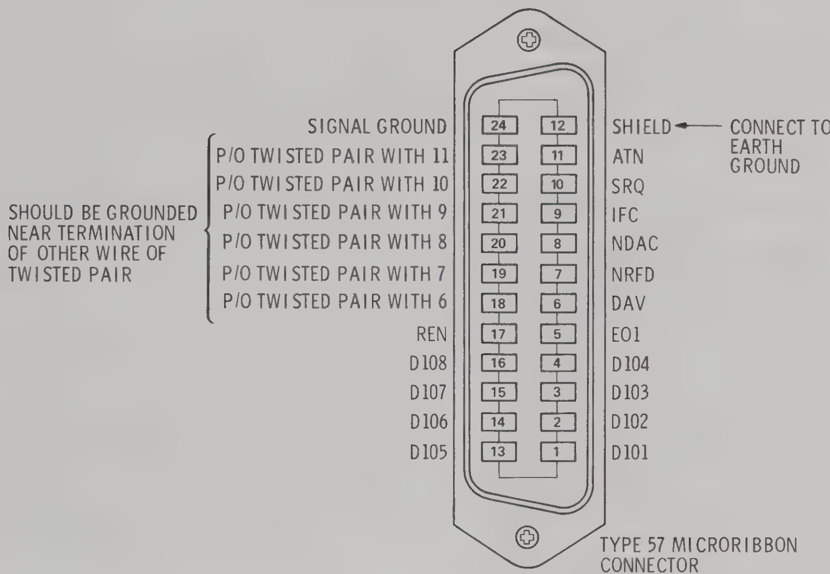
Assembly	Service Sheet	Jumper Functions
A-D Converter Assembly A3	8	The factory-installed jumpers provide a filtered dc RECORDER OUTPUT which corresponds to the average power input to the Power Sensor. If external filtering is desired, reconnect the jumpers to provide the optional unfiltered dc RECORDER OUTPUT as shown on Service Sheet 8.

Table 2-3. USA Standard Code for Information Interchange (ASCII)

BITS b_7 b_6 b_5					0_{0_0}	0_{0_1}	0_{1_0}	0_{1_1}	1_{0_0}	1_{0_1}	1_{1_0}	1_{1_1}
b_4 ↓	b_3 ↓	b_2 ↓	b_1 ↓	Column→ Row↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	¦
1	1	0	1	13	CR	GS	–	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

NOTE 3 (columns b_7 b_6 b_5 and b_4–b_1); NOTE 1 (columns 2–3); NOTE 2 (columns 4–5)

NOTE 1: HP-IB valid LISTEN addresses
NOTE 2: HP-IB valid TALK addresses
NOTE 3: Logic 1 = 0V



Logic Levels

The Hewlett-Packard Interface Bus logic levels are TTL compatible, i.e., the true (1) state is 0.0 Vdc to 0.4 Vdc and the false (0) state is +2.5 Vdc to +5.0 Vdc.

Programming and Output Data Format

Refer to Section III, Operation.

Mating Connector

HP 1251-0293; Amphenol 57-30240.

Mating Cables Available

HP 10631A, 1.0 metre (3 ft.); HP 10631B, 2.0 metres (6 ft.)
HP 10631C, 4.0 metres (12 ft.); HP 10631D, 0.5 metre (1.5 ft.)

Cabling Restrictions

1. A Hewlett-Packard Interface Bus System may contain no more than 1.8 metres (6 ft.) of connecting cable per instrument.
2. The maximum accumulative length of connecting cable for any Hewlett-Packard Interface Bus System is 20.0 metres (65.6 ft.)

Figure 2-3. Hewlett-Packard Interface Bus Connection

SECTION III
OPERATION

3-1. INTRODUCTION

3-2. This section provides complete operating information for the Power Meter. Included in the section are a description of all front- and rear-panel controls, connectors, and indicators (panel features), operator's checks, operating instructions, power measurement accuracy considerations, and operator's maintenance.

3-3. Since the power meter can be operated locally as well as remotely via the Hewlett-Packard Interface Bus (Option 022), the information in this section is arranged accordingly. All information unique to a particular operating configuration is designated as such; where no distinction is made, the information is applicable to both standard and optional instrument operation.

3-4. PANEL FEATURES

3-5. Front and rear panel features of the Power Meter are described in Figure 3-1. This figure contains a detailed description of the controls, connectors and indicators.

3-6. OPERATOR'S MAINTENANCE

3-7. The only maintenance the operator should normally perform is replacement of the primary power fuse located within Line Module Assembly A11. For instructions on how to change the fuse, refer to Section II, Line Voltage Selection.

CAUTION

Make sure that only fuses with the required rated current and of the specified type (normal blow, time delay, etc.) are used for replacement. The use of repaired fuses and the short-circuiting of fuse-holders must be avoided.

3-8. OPERATOR'S CHECKS

3-9. A procedure for verifying the major functions of the Power Meter is provided in Figure 3-2. The procedure is divided into two parts: Local Operation and Remote Hewlett-Packard Interface Bus Operation. For a standard instrument it is only necessary to perform the Local Operation procedure. For units equipped with the remote option, the Local Operation procedure should be performed first to establish a reference against which remote operation can be verified. Information covering remote programming of the Power Meter is provided in the following paragraphs, and a Hewlett-Packard Interface Bus Verification Program is provided in Section VIII, Service.

3-10. LOCAL OPERATING INSTRUCTIONS

3-11. Figure 3-3 provides general instructions for operating the Power Meter via the front-panel controls.

WARNING

Any interruption of the protective (grounding) conductor (inside or outside the instrument) or disconnecting the protective earth terminal is likely to make this instrument dangerous. Intentional interruption is prohibited.

FRONT AND REAR PANEL FEATURES

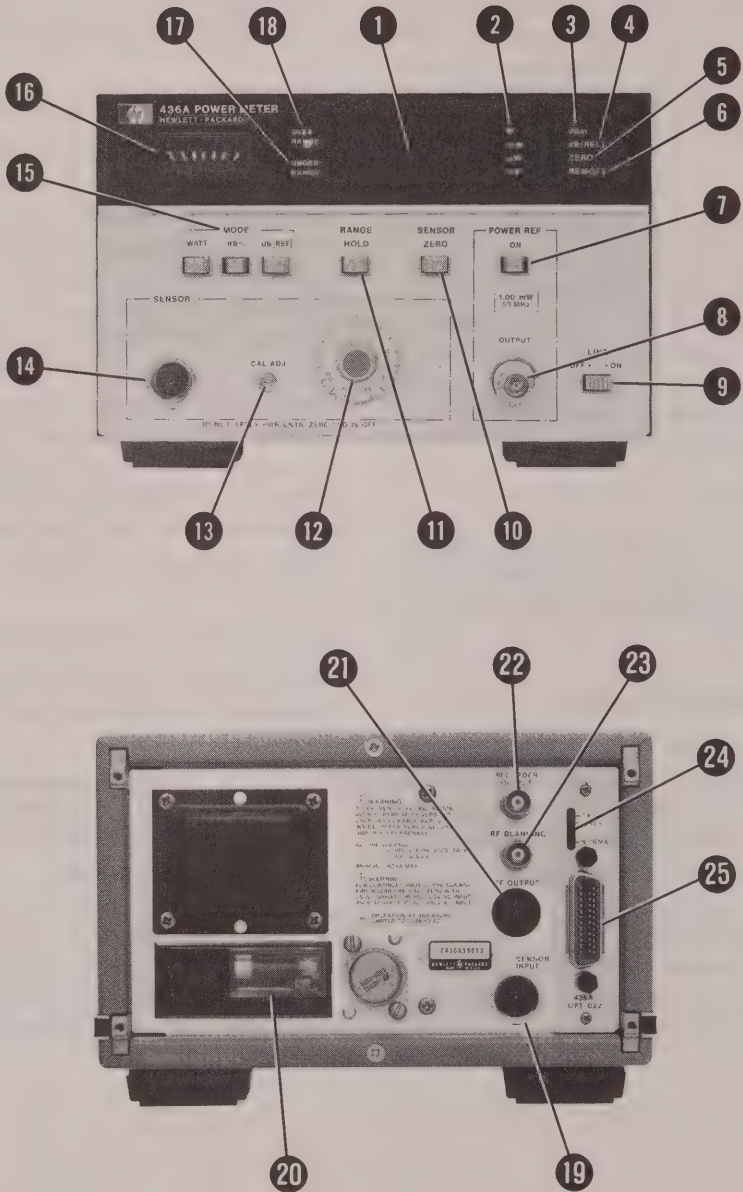


Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (1 of 4)

FRONT PANEL FEATURES

1 **Digital Readout:** Indicates sign and decimal value of RF input power in Watts, dBm, or in dB relative to a stored reference.

2 **Range Lamps (W,mW, μW, nW):** Enabled in WATT MODE. Light to indicate level of Digital Readout indication.

3 **dBm:** Lights to indicate that dBm MODE is selected and Digital Readout indication is in dBm.

4 **dB (REL):** Lights to indicate that dB RELATIVE MODE is selected and Digital Readout indication is in dB with respect to stored reference level.

5 **ZERO:** Lights to indicate that power sensor auto-zero circuit is enabled and 23 RF BLANKING output is active.

6 **REMOTE:** Associated with the Hewlett-Packard Interface Bus Option 022. Lights to indicate that front-panel switches are disabled and power meter operation is being controlled via remote interface.

7 **POWER REF ON:** Alternate action pushbutton switch. When set to ON (in), enables 8 POWER REF OUTPUT.

8 **POWER REF OUTPUT:** Enabled when 7 POWER REF switch is set to ON. Provides RF output of 1.00 mW ± 0.70% for system calibration.

9 **LINE ON-OFF:** Alternate action pushbutton switch. Applies ac line power to Power Meter when set to ON (in).

10 **SENSOR ZERO:** Spring-loaded pushbutton switch. When pressed, enables Power Sensor auto zero loop for a period of approximately 4 seconds (5 ZERO lamp remains lit for the duration of this period).

NOTE

In order to auto-zero the Power Sensor, no RF input power may be applied while the 5 ZERO lamp is lit. If any RF input power is applied, it will introduce an offset that will affect all subsequent measurements.

11 **RANGE HOLD:** Alternate action pushbutton switch. When set to off (out) allows Power Meter to autorange as required to track changes in RF input power level. When set to on (in), locks Power Meter in last range enabled during autoranging.

12 **CAL FACTOR %:** Rotary switch which changes the gain of the Power Meter amplifier circuits to compensate for mismatch losses and effective efficiency of the Power Sensor. A chart of CAL FACTOR % versus frequency is printed on each Power Sensor.

13 **CAL ADJ:** Screwdriver adjustment for calibrating the Power Meter and any Power Sensor to a known standard.

14 **SENSOR:** Provides input connection for Power Sensor via Power Sensor Cable.

15 **MODE:** Interlocking pushbutton switches which configure the Power Meter to indicate average RF input power in watts, in dBm, or in dB with respect to a stored reference.

WATT: Alternate action pushbutton switch. When set to on (in), selects WATT Mode. (Power Meter is configured to indicate RF input power in watts, milliwatts, microwatts, or nanowatts.

dBm: Alternate action pushbutton switch. When set to on (in), selects dBm Mode. (Power Meter is configured to indicate RF input power in dBm.)

dB [REF]: Spring-loaded pushbutton switch. When pressed, selects dB Relative Mode. (RF input power level displayed on 1 Digital Readout is stored as dB reference and 1, Digital Readout changes to 0. Then Power Meter is configured to indicate changes in RF input level in dB with respect to stored reference.)

NOTE

When the dB relative mode is selected, the WATT Mode or dBm Mode can be selected by pressing the 15 WATT MODE or dBm Mode switch and the power applied to the Sensor is displayed on the 1 Digital

(continued)

Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (2 of 4)

FRONT AND REAR PANEL FEATURES

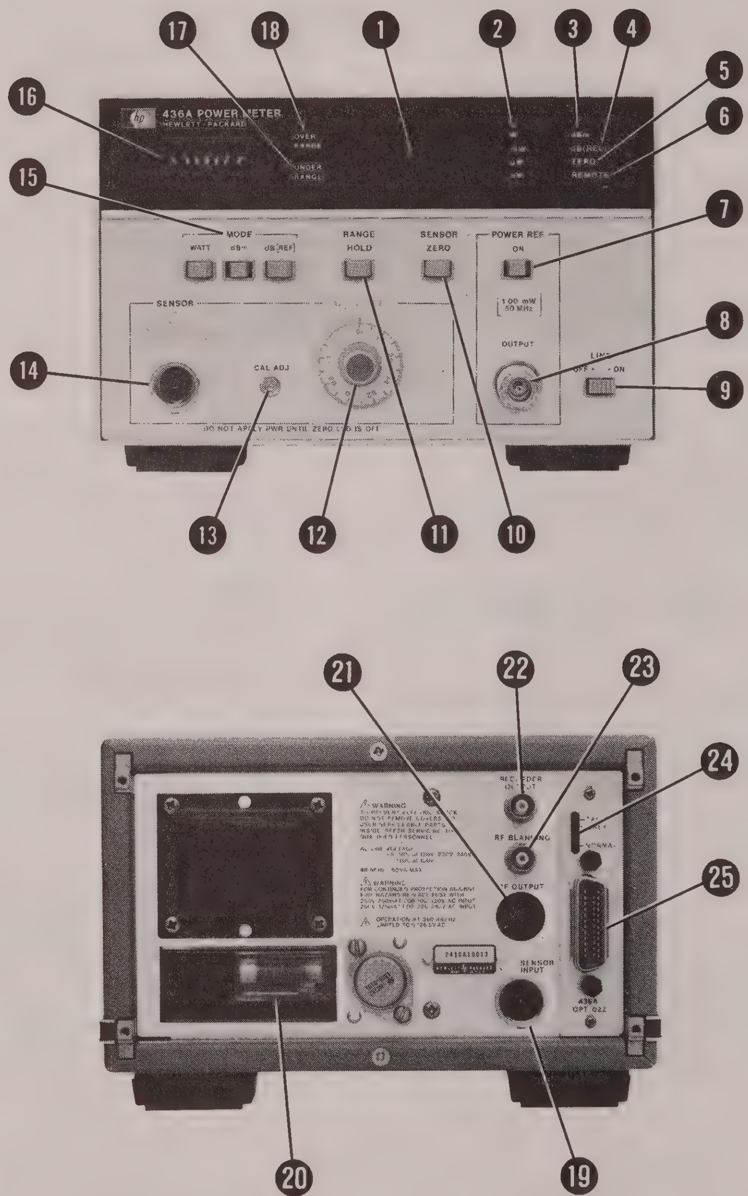


Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (3 of 4)

FRONT PANEL FEATURES (cont'd)

(Note cont'd)

Readout. To return to the dB Relative Mode without changing the stored reference, press the 15 *WATT MODE or dBm MODE switch just enough to release the previously selected MODE switch. Do not press the* 15 *dB [REF] MODE switch or a new reference will be entered.*

WARNING

Any interruption of the protective (grounding) conductor inside or outside the instrument or disconnecting of the protective earth terminal is likely to make the instrument dangerous. Intentional interruption is prohibited. (See Section II.)

16 **Auxiliary Meter:** Provides a linear display with respect to RF input power. For any given range, a full-scale meter indication corresponds to the highest indication that can be obtained on the Digital Display.

17 **UNDER RANGE:** Lights to indicate that RF input power level is too small to be measured on selected range (autoranging disabled), or on Power Meter lowest range (autoranging enabled).

18 **OVER RANGE:** Lights to indicate that RF input power level is too large to be measured on selected range (autoranging disabled), or on Power Meter highest range (autoranging enabled).

REAR PANEL FEATURES

19 **SENSOR INPUT:** This rear panel input is wired in parallel with the front panel input 14 .

20 **Line Power Module:** Permits operation from 100, 120, 220, or 240 Vac. The number visible in window indicates nominal line voltage to which instrument must be connected (see Figure 2-1). Protective grounding conductor connects to the instrument through this module.

21 **POWER REF OUTPUT:** Takes the place of the front panel 8 POWER REF OUTPUT connector (Option 003 only).

22 **RECORDER OUTPUT:** Provides a linear output with respect to the input power. +1.00 Vdc corresponds to a full scale 1 Digital Readout indication on the range selected (refer to Table 1-1). The minimum load which may be coupled to the output is 1 MΩ.

23 **RF BLANKING:** Contact closure to ground when 10 SENSOR ZERO switch is pressed. May be used to remove RF input signal during automatic zeroing operation.

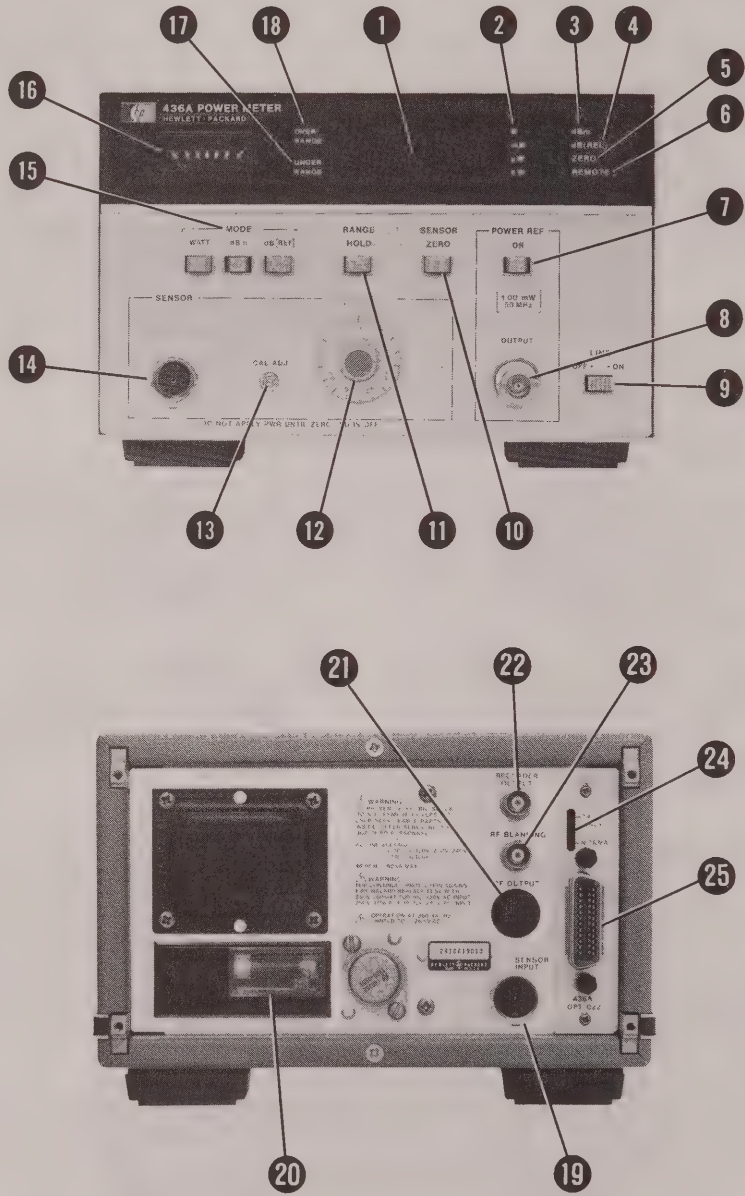
24 **TALK ONLY/NORMAL:** Associated with Hewlett-Packard Interface Bus Option 022 only. NORMAL position configures the Power Meter as a basic talker. TALK ONLY position is normally used only when there is no controller connected to the interface bus (e.g., when Power Meter is interconnected with an HP 5150A recorder).

25 **Interface Connector:** For Power Meter connection to remote interface Option 022.

Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (4 of 4)

OPERATOR'S CHECKS

LOCAL OPERATION



WARNINGS

BEFORE CONNECTING LINE POWER TO THIS INSTRUMENT, ensure that all devices connected to this instrument are connected to the protective (earth) ground.

BEFORE SWITCHING ON THIS INSTRUMENT, ensure that the line power (mains) plug is connected to a three-conductor line power outlet that has a protective (earth) ground. (Grounding one conductor of a two-conductor outlet is not sufficient.)

Figure 3-2. Operator's Checks (1 of 5)

OPERATOR'S CHECKS

LOCAL OPERATION (cont'd)

1. BEFORE SWITCHING ON THIS INSTRUMENT, ensure that the power transformer primary is matched to the available line voltage, the correct fuse is installed, and the safety precautions are taken. See Power Requirements, Line Voltage Selection, Power Cables, and associated warnings and cautions in Section II.

NOTE

If Power Meter is equipped with the Hewlett-Packard Interface Bus option, unplug data bus cable from connector J7 on rear panel before performing this procedure. When data bus cable is unplugged, Power Meter is automatically configured for Local operation via front-panel controls.

CAUTION

DO NOT TWIST the body of the power sensor when connecting or disconnecting it to other instruments. Twisting may cause major damage to the power sensor electrical circuits.

2. Connect the Power Sensor to the Power Meter with the Power Sensor Cable.

3. Connect the Power Sensor to the 8 POWER REF OUTPUT connector.

4. Connect the Power Cable to the power outlet and 20 Line Power Module receptacle, and set the 9 LINE switch to ON (in).

5. Set the remaining Power Meter switches as follows:

12 CAL FACTOR%	Set to reference calibration factor.
7 POWER REF	off (out)
15 MODE	WATT
11 RANGE HOLD	off (out)

NOTE

Perform steps 6 through 19 only if Power Meter is connected to 8481A, 8482A, or 8483A Power Sensor. If Power Meter is connected to 8481H or 8482H Power Sensor, proceed to step 20.

6. Press and hold the 10 SENSOR ZERO switch until the digital readout stabilizes. While the switch is held depressed, verify that the 5 ZERO lamp is lit and that the 23 RF BLANKING output is 0.0±0.4V.

7. Release the 10 SENSOR ZERO switch and verify that the 5 ZERO lamp remains lit for approximately four seconds. When the 5 ZERO lamp goes out, verify that the 1 Digital Readout indicates 0.00±0.02 μW.

8. Set the 11 RANGE HOLD and 7 POWER REF switches to ON (in). Verify that the 18 OVER-RANGE lamp lights and that the 1 Digital Readout blanks (1_._μW).

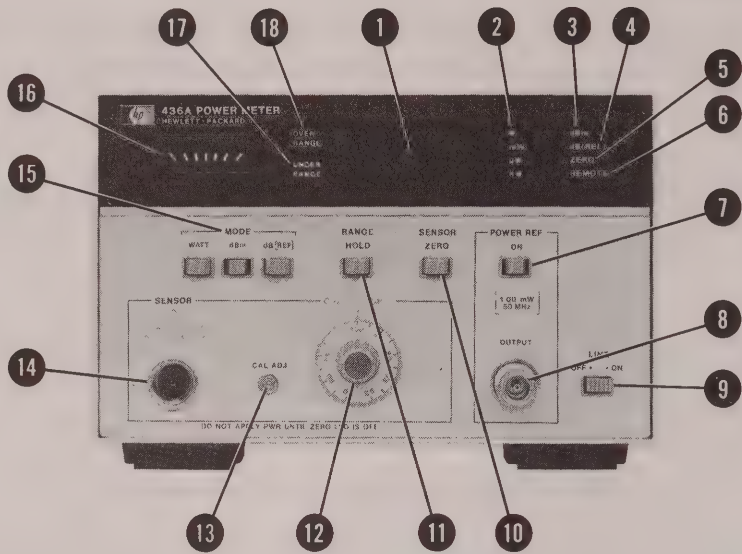
9. Set the 11 RANGE HOLD switch to off (out). Verify that the Power Meter autoranges to the 1 mW range and that the 18 OVER RANGE lamp goes out.

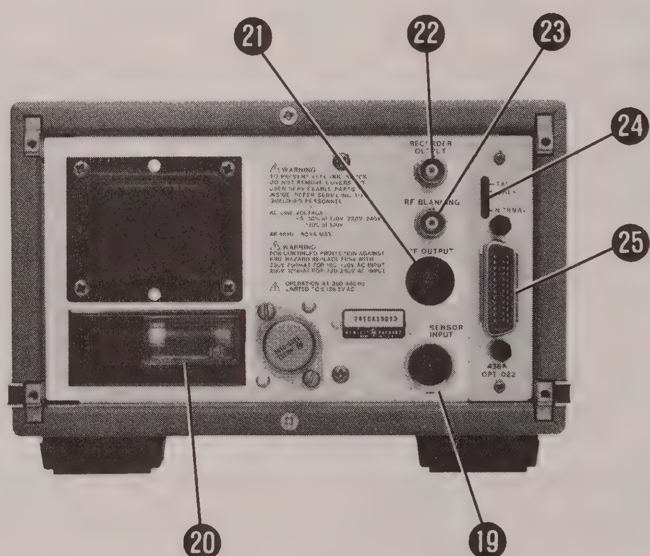
10. Adjust the 13 CAL ADJ control so that the 1 Digital Readout indicates 1.000 mW. Verify that the pointer on the 16 Auxiliary Meter is aligned between the last two marks, and that the 22 RECORDER OUTPUT is approximately 1.000 Vdc.

Figure 3-2. Operator's Checks (2 of 5)

OPERATOR'S CHECKS

LOCAL OPERATION (cont'd)





NOTE

Underscore (_) indicates blanked digit.

11. Rotate the 12 CAL FACTOR % switch through its range and verify that the 1 Digital Readout indication increases slightly for each successive step. Then return the 12 CAL FACTOR % switch to 100.

Figure 3-2. Operator's Checks (3 of 5)

OPERATOR'S CHECKS

LOCAL OPERATION (cont'd)

12. Set the 15 dBm MODE switch to on (in) and verify that the 1 Digital Readout indicates —0.0 ± 0.01 dBm.

13. Set the 11 RANGE HOLD switch to on (in) and the 7 POWER REF switch to off (out). Verify that the 17 UNDER RANGE lamp lights and that the 1 Digital Readout blanks (—1_ . _ dBm).

14. Set the 11 RANGE HOLD switch to off (out) and verify that the 1 Digital Readout blanked indication changes to —3 _ . _. The new indication verifies that the Power Meter has autoranged to the most sensitive dBm range.

15. Set the 11 RANGE HOLD and 7 POWER REF switches to ON (in). Verify that the 18 OVER RANGE lamp lights and that the 1 Digital Readout blanked indication changes to —1_ . _ .

16. Set the 11 RANGE HOLD switch to off (out) and verify that the 1 Digital Readout indicates —0.00 ± 0.01 dBm. This new indication verifies that the Power Meter has autoranged properly.

17. Adjust the 13 CAL ADJ control so that the 1 Digital Readout indicates —1.40 dBm.

18. Press the 15 dB [REF] MODE switch and verify that the 3 dBm lamp goes out, the 4 dB (REL) lamp lights, and the 1 Digital Readout changes to —0.00. This step verifies that the Power Meter can store a dB reference value and indicate RF input power levels in dB with respect to the stored reference.

19. Set the 15 WATT Mode switch to on (in) and readjust the 13 CAL ADJ control so that the 1 Digital Readout indicates 1.000 mW.

NOTE

Steps 20 through 28 are performed in lieu of steps 6 through 19 when the Power Meter is connected to an 8481H or an 8482H Power Sensor.

20. Press and hold the 10 SENSOR ZERO switch until the 1 Digital Readout stabilizes. While the switch is held pressed, verify that the 5 ZERO lamp is lit and that the 23 RF BLANKING output is 0.0 ± 0.4V.

21. Release the 10 SENSOR ZERO switch and verify that the 5 ZERO lamp remains lit for approximately four seconds. When the 5 ZERO lamp goes out, verify that the 1 Digital Readout indicates 0.00 ± 0.02 mW.

22. Set the 7 POWER REF switch to ON (in) and adjust the 13 CAL ADJ control so that the 1 Digital Readout indicates 1.000 mW. Verify that the pointer on the 16 Auxiliary Meter is aligned between the last two marks, and that the 22 RECORDER OUTPUT is approximately 1.000 Vdc.

23. Rotate the 12 CAL FACTOR % switch through its range and verify that the 1 Digital Readout increases slightly for each successive step. Then return the 12 CAL FACTOR % switch to 100.

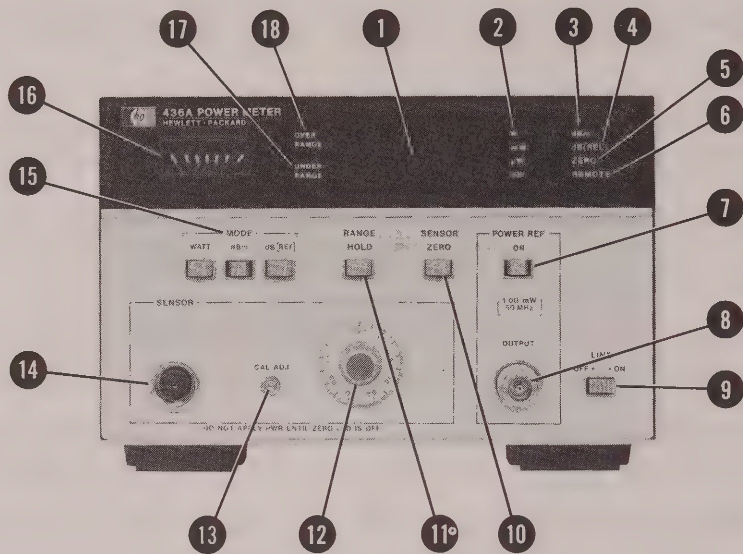
24. Set the 15 dBm MODE switch to on (in) and verify that the 1 Digital Readout indicates —0.00 ± 0.01 dBm.

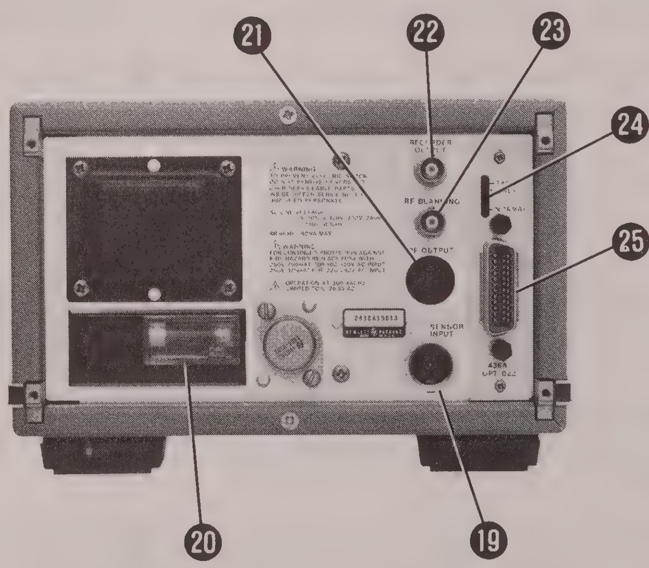
25. Set the 7 POWER REF switch to off (out). Verify that the 17 UNDER RANGE lamp lights and that the 1 Digital Readout blanks (—1 _ . _ dBm).

Figure 3-2. Operator's Checks (4 of 5)

OPERATOR'S CHECKS

LOCAL OPERATION (cont'd)





26. Set the 7 POWER REF switch to ON (in) and adjust the 13 CAL ADJ control so that the 1 Digital Readout indictes −2.00 dBm.

27. Press the 15 dB [REF] Mode switch and verify that the 3 dBm lamp goes out, the 4 dB (REL) lamp lights, and the 1 Digital Readout changes to −0.00. This step verifies that the Power Meter can store a dB reference value and indicate input power levels in dB with respect to the stored reference.

28. Set the 15 WATT Mode switch to on (in) and readjust the 13 CAL ADJ control so that the 1 Digital Readout indicates 1.000 mW.

Figure 3-2. Operator's Checks (5 of 5)

OPERATING INSTRUCTIONS

LOCAL OPERATION

1. BEFORE SWITCHING ON THIS INSTRUMENT, ensure that the power transformer primary is matched to the available line voltage, the correct fuse is installed, and safety precautions are taken. See Power Requirement, Line Voltage Selection, Power Cables, and associated warnings and cautions in Section II.

NOTE

If Power Meter is equipped with the Hewlett-Packard Interface Bus Option, either unplug data bus cable from connector J7 on rear panel or program Power Meter for Local operation as described under Operating Instructions paragraph.

CAUTION

DO NOT TWIST the body of the power sensor when connecting or disconnecting it to other instruments. Twisting may cause major damage to the power sensor's electrical circuits.

2. Connect the Power Sensor to the Power Meter with the Power Sensor Cable.

3. Connect the Power Cable to the power outlet and (20) Line Power Module receptacle and set the (9) LINE ON-OFF switch to ON (in).

4. Set the remaining Power Meter switches as follows:

(12) CAL FACTOR %	100
(7) POWER REF	off (out)
(15) MODE	WATT
(11) RANGE HOLD	off (out)

5. Press and hold the (10) SENSOR ZERO switch and wait for the (1) Digital Readout to stabilize. Then verify that the (5) ZERO lamp is lit and that the (1) Digital Readout indicates 0.00 ±0.02.

NOTE

When auto-zeroing the Power Sensor, no RF input power may be applied while the ZERO lamp is lit. If any RF input power is applied, it will introduce an offset that will affect subsequent measurements.

6. Release the (10) SENSOR ZERO switch and wait approximately 4 seconds for the (5) ZERO lamp to go out.

7. Connect the Power Sensor to the (8) POWER REF OUTPUT connector and set the (7) POWER REF switch to ON (in). Then adjust the (13) CAL ADJ control so that the (1) Digital Readout indicates 1.000 mW.

8. Set the (7) POWER REF switch to off (out) and disconnect the Power Sensor from the (8) POWER REF OUTPUT connector.

9. Locate the calibration curve on the Power Sensor cover and determine the CAL FACTOR for the measurement frequency; set the Power Meter (12) CAL FACTOR % switch accordingly.

CAUTION

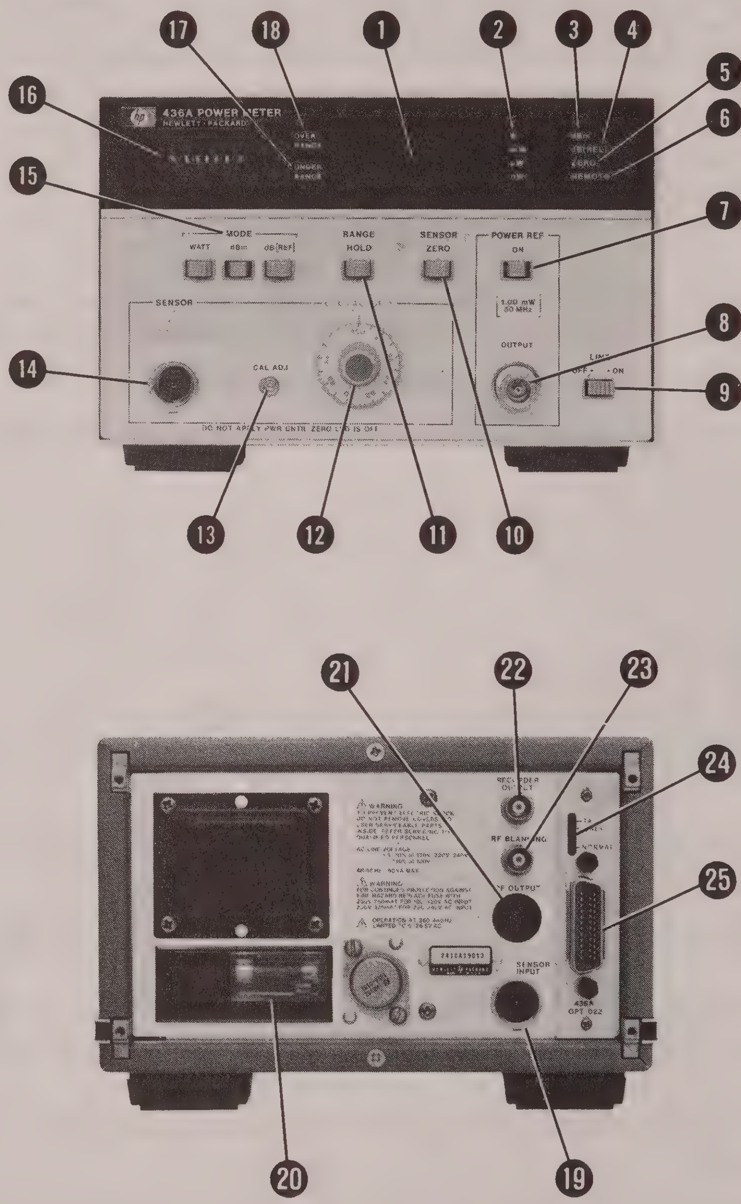
See Operating Precautions in the Power Sensor Operating and Service Manuals for maximum power levels which may be safely coupled to this system. Levels which exceed the limits may damage the Power Sensor, Power Meter or both.

10. Set the (15) MODE and (11) RANGE HOLD switches for desired operation and connect the Power Sensor to the RF source.

Figure 3-3. Operating Instructions (1 of 3)

OPERATING INSTRUCTIONS

HEWLETT-PACKARD INTERFACE BUS (HP-IB) OPERATION



WARNINGS

BEFORE CONNECTING LINE POWER TO THIS INSTRUMENT, ensure that all devices connected to this instrument are connected to the protective (earth) ground.

BEFORE SWITCHING ON THIS INSTRUMENT, ensure that the line power (mains) plug is connected to a three-conductor line power outlet that has a protective (earth) ground. (Grounding one conductor of a two-conductor outlet is not sufficient.)

Figure 3-3. Operating Instructions (2 of 3)

OPERATING INSTRUCTIONS

HP-IB OPERATION (cont'd)

1. BEFORE SWITCHING ON THIS INSTRUMENT, ensure that the power transformer primary is matched to the available line voltage, the correct fuse is installed, and safety precautions are taken. See Power Requirement, Line Voltage Selection, Power Cables, and associated warnings and cautions in Section II.

CAUTION

DO NOT TWIST the body of the power sensor when connecting or disconnecting it to other instruments. Twisting may cause major damage to the power sensor's electrical circuits.

2. Connect the Power Sensor to the Power Meter with the Power Sensor Cable.
3. Connect the Power Meter to the **Remote Interface** 25.
4. Connect the Power Cable to the power outlet and 20 Line Power Module receptacles and set the 9 LINE ON-OFF switch to ON (in).
5. Set the Power Meter 12 CAL FACTOR % switch to 100 and the 7 POWER REF switch to off (out).
6. Set the remote enable input to the Power Meter to logical 1 (0.0 ± 0.4 Vdc) and program the Power Meter as follows:

Mode	WATT
Range	AUTO
10 SENSOR ZERO	ON
12 CAL FACTOR %	enabled

7. Wait for the 1 Digital Readout to stabilize, then verify that the 5 ZERO lamp is lit and that the 1 Digital Readout indicates 0.00 ± 0.02.

NOTE

When auto-zeroing the Power Sensor, no RF input power may be applied while the 5 ZERO lamp is lit. If any RF input power is applied, it will introduce an offset that will affect subsequent measurements.

8. Program the 10 SENSOR ZERO function to off by programming one of the other modes (WATT, dBm or dB Ref) and wait approximately 4 seconds for the 5 ZERO lamp to go out.
9. Connect the Power Sensor to the 8 POWER REF OUTPUT connector and set the 7 POWER REF switch to ON (in). Then adjust the 13 CAL ADJ control so that the 1 Digital Readout indicates 1.000 mW.
10. Set the 7 POWER REF switch to off (out) and disconnect the Power Sensor from the 8 POWER REF OUTPUT connector.
11. Locate the calibration curve on the Power Sensor to cover and determine the CAL FACTOR for the measurement frequency; set the Power Meter 12 CAL FACTOR % switch accordingly.

CAUTION

See Operating Precautions in the Power Sensor Operating and Service Manuals for maximum power levels which may be safely coupled to this system. Levels which exceed the limits may damage the Power Sensor, Power Meter or both.

12. Program the Power Meter to the desired Mode and Range, select the triggering most appropriate to the type of measurements anticipated, and connect the Power Sensor to the RF source.

Figure 3-3. Operating Instructions (3 of 3)

3-12. HEWLETT-PACKARD INTERFACE BUS REMOTE OPERATION

NOTE

For a quick and easy programming guide see Figure 3-8; for detailed information study paragraphs 3-12 through 3-61.

3-13. Hewlett-Packard Interface Bus (HP-IB) Option 022 adds remote programming and digital output capability to the Power Meter. For further information about the HP-IB, refer to IEEE Standard 488 and the Hewlett-Packard Catalog. Power Meter compatibility, programming, and data format is described in detail in the paragraphs which follow.

3-14. Compatibility

3-15. The Power Meter controls that can be programmed via the Hewlett-Packard Interface Bus are the MODE and SENSOR ZERO switches. The controls not programmable are the POWER REF and LINE switches. The CAL FACTOR % switch can be enabled and disabled via the interface bus but, when enabled, the calibration factor entered at the front-panel of the Power Meter is used.

3-16. In addition, specific ranges can be set and various triggering options are available to the programmer. This will be described in detail later.

3-17. The programming capability of the Power Meter will be described in terms of the twelve bus messages found in Table 3-1.

3-18. Data Messages

3-19. The Power Meter communicates on the bus primarily through data messages. It receives data messages that tell it what range to use, what mode to use, whether or not cal factor should be enabled, and what the measurement rate should be. It sends data messages that tell the measurement value, the mode and range the value was taken at, and what the instrument's status (see Table 3-4) was when it took the measurement.

3-20. Table 3-2 outlines the key elements involved in making a measurement. Indeed the Power Meter can be programmed to make measurements via the HP-IB by following only the sequence suggested in the table, and briefly referring to Tables 3-3, 3-4, (input and output data), and Fig. 3-8. However, to take advantage of the programming flexibility built into the Power Meter and minimize the time it takes to make a valid measurement, study the rest of the information in this section.

3-21. Receiving Data Messages

3-22. The Power Meter is configured to listen (receive data) when the controller places the interface bus in the command mode (ATN and REN lines low; IFC line high) and outputs listen address "—" (minus sign). The Power Meter then remains configured to listen (accept programming inputs when the interface bus is in the data mode) until it is unaddressed by the controller. To unaddress the Power Meter, the controller can either send the Abort Message (set the IFC line low) or send the Local Message (set the REN line high), or it can place the interface bus in the command mode and generate a universal unlisten command.

3-23. Data Input Format. The Power Meter does not require any particular data input format. It is capable of responding to each of the programming codes listed in Table 3-3 on an individual basis. Because it responds to these codes in the order it receives them, we recommend that the code for measurement rate be sent last.

3-24. Program Codes. Table 3-3 lists the program codes that the Power Meter responds to and the functions that they enable. In the listen mode, the Power Meter can handshake in 0.5 μs. The time required for the Power Meter to respond to the programming command, however, depends on where the Power Meter is in the operating program (see Figure 3-6). The overall worst case time for Power Meter response to a programming command is 2.5 seconds, the minimum response time is approximately 100 microseconds.

NOTE

In addition to the program codes listed in Table 3-3, Power Meter operation will be affected by all other program codes shown in columns 2, 3, 4, and 5 of Table 2-2, except (SP!"#$%&). Thus care should be taken to address the Power Meter to unlisten before sending these programming commands to other instruments on the interface bus.*

3-25. Programming the Range. Remote range programming is slightly different than Local range selection. For Local operation the Power Meter auto-ranges. For Remote operation, the program codes have provision for direct selection of the de-

Table 3-1. Message Reference Table

Message and Identification	Applicable	Command and Title	Response
Data	Yes	T3 Talker, L2 Listener, AH1 Acceptor Handshake SH1 Source Handshake.	Power Meter changes mode, range, measurement rate, and Cal Factor enable or disable. It outputs status and measurement data.
Trigger (DT0)	No	Device Trigger	The Power Meter does not respond to a Group Execute Trigger. However, remote trigger capability is part of the Data message (measurement rate).
Clear (DC2)	Yes No	DCL Device Clear SDC Selected Device Clear	Upon receipt of DCL command, Power Meter functions are set for Watt Mode, Auto Range, Cal Factor Disable and Measurement rate Hold.
Remote (RL2)[1]	Yes	REN Remote Enable	Power Meter goes to remote when addressed to listen, and REN is true (low).
Local (RL2)[1]	Yes No	REN Remote Disable GTL Go to Local	Power Meter goes to local when REN is false (high). Power Meter does not respond to GTL command.
Local Lockout (RL2)[1]	No	REN Remote Disable	Power Meter does not respond to LLO command.
Clear Lockout/ Set Local (RL2)[1]	Yes	REN Remote Disable	Returns all devices on bus to local operation.
Pass Control/Take Control (CØ)	No	Controller	Power Meter cannot act as bus controller.
Require Service (SRØ)	No	SRQ Service Request	Power Meter does not request service.
Status Byte	No	SPE Serial Poll Enable SPD Serial Poll Disable	Power Meter does not respond to a Serial Poll
Status Bit (PPØ)	No	PP Parallel Poll	Power Meter does not respond to a parallel poll.
Abort	Yes	IFC Interface Clear	Power Meter stops talking or listening.

[1]The 436A does not have complete RL2 capability since it cannot process the Go-To-Local (GTL) message.

NOTE

Complete HP-IB capability as defined in IEEE Std. 488 is AH1, C0, DC2, DT0, LE0, PP0, RL2, SH1, SR0, T3, TE0.

Table 3-2. Measurement Sequence

MEASUREMENT SEQUENCE

Event 1 {controller talk and Power Meter listen} , {Program Codes}

See controller manual. Power Meter Listen address factory set to "—" (see Tables 2-1 and 2-2).
e.g., **CMD "?U–","9D+V"**
wrt "pmrd", "9D+V"

Program codes to configure one or more of the following (see Table 3-3):

1. Range
2. Remote mode (Watt, dBm, dB [Ref]
3. Cal Factor
4. Measurement Rate (and trigger)

Event 2 Response time for meter's digital (operating program) circuitry (see Table 3-5 and Figures 3-5 and 3-6).

Event 3 Meter takes measurement; data available.

Event 4 Additional delay to allow analog circuits to settle; necessary only if on Range 1 (most sensitive) or if settling time measurement rates are not being used (see Figure 3-4). Here are some suggestions:*

1. Load reading into controller (event five) and check data string for range (look at character number 1 or check measured value).
2. If Power Meter is on Range 1, wait 10 seconds and take another reading.
3. If settling time measurement rates are being used and meter is *not* on Range 1, use the first reading.
4. If settling time measurement rates are *not* being used, determine the range and branch to an appropriate delay: Range 2, one second; Ranges 3-5, 0.1 second.

Event 5 {universal unlisten, controller listen and Power Meter talk} , {variable name}

See controller manual. Power Meter Talk address factory set to "M" (see Tables 2-1 and 2-2).

*There are other ways to ensure that readings are not affected by analog circuit settling time. Also, these recommended delays are worst case. A thorough understanding of the material in this section will allow you to optimize measurement time for your particular application. For example, if the power level is not changing, the controller can average at least two consecutive readings to see if the result is still settling.

EXAMPLE PROGRAM SEQUENCE:

Line 1 {controller talk and power meter listen}, **"9D+T"**

- 9 — Auto Range
- D — dBm Mode
- + — Cal Factor Disable (100%)
- T — Measurement Rate: Trigger with settling time.

Line 2 {universal unlisten, controller listen and power meter talk} , {variable name}

Power meter outputs measured value to controller.

Line 3 {Controller checks value in variable for Range 2 threshold (e.g., <–20 dBm for Model 8482A Power Sensor). If value is below threshold, program branches to line 4. If value is above threshold, program branches to line 5.}

Line 4 {wait 10 seconds, then go to line 1 } .

Line 5 {continue} .

Table 3-3. Hewlett-Packard Interface Bus Input Program Codes

Function	Program Codes ASC II	Program Codes DECIMAL
Range		
Least sensitive	5	53
	4	52
	3	51
	2	50
Most sensitive	1	49
Auto	9	57
MODE		
Watt	A	65
dB (Rel)	B	66
dB [Ref]	C	67
dBm	D	68
Sensor auto-zero	Z	90
CAL FACTOR		
Disable (100%)	+	43
Enable (front-panel switch setting)	—	45
Measurement Rate		
Hold	H	72
Trigger with setling time	T	84
Trigger, immediate	I	73
Free Run at maximum rate	R	82
Free Run with setling time	V	86

sired range as well as for selection of the autorange function.

3-26. Programming the Mode. Remote mode programming is similar to Local mode selection. The sequence shown in Example 1 is recommended for taking dB (Rel) readings from a dB [Ref] reference.

3-27. Programming Auto-Zero. The Power Meter is remotely zeroed the same way it is zeroed in local. Example 2 shown on the next page outlines the program steps that should be written. Specific examples are provided later in this Section. (Refer to Tables 3-3 and 3-4 for Power Meter input and output strings. Refer to controller manual for programming syntax.)

3-28. Programming Cal Factor. While the setting of the front panel CAL FACTOR switch cannot be remotely changed, the programmer does have a choice. If CAL FACTOR enable is programmed, then the Power Meter uses the Cal Factor set by the switch. If CAL FACTOR Disable is programmed, then the Power Meter uses a Cal Factor of 100%, but the program can correct for cal factor by computing the corrected reading from the actual reading and the cal factor (a Cal Factor table must be stored in an array).

3-29. Programming Measurement Rate. A feature that is only available via remote programming is selection of standby, triggered, or free running operation of the Power Meter. (During Local operation, the Power Meter is allowed to free run with approximately 133 milliseconds allowed for settling time between measurements.) The specific remote triggering capabilities are:

a. **Hold (H)** — when the power meter is programmed to Hold, it is inhibited from taking measurements and from outputting data. Thus, it is set to a predetermined reference condition from which a measurement can be triggered synchronously to some external event.

b. **Trigger Immediate (I)** — this programming command directs the Power Meter to make one measurement and output the data in the minimum possible time, then to go into Hold until the next triggering command is received. It does not allow settling time prior to the measurement.

c. **Trigger with Delay (T)** — this trigger command is identical to the trigger immediate command except that it causes the Power Meter to execute a settling-time delay subroutine before taking a measurement and outputting data.

EXAMPLE 1 (dB Rel/dB Ref)

1	{controller talk and Power Meter listen}, **"CT"**	Sets reference at present RF input level.
2	{controller talk and Power Meter listen}, **"BT"**	Takes first reading relative to set reference
3	{universal unlisten, controller listen and Power Meter talk}, {Variable name}	Power Meter outputs reading to controller
4	{controller talk and Power Meter listen}, **"T"**	Takes subsequent readings
5	{universal unlisten, controller listen and Power Meter talk}, {Variable name}	Power Meter outputs reading to controller

Receiving Data Messages (cont'd)

d. **Free run at maximum rate (R)** — this programming command is normally used for asynchronous operation of the Power Meter. It directs the Power Meter to continuously take measurements and output data in the minimum possible time. It does not allow settling time prior to each measurement.

e. **Free run with delay (V)** — this programming command is identical to the previous command except that it causes the Power Meter to execute a settling-time delay subroutine prior to each measurement.

3-30. When programming the Power Meter for synchronous triggered operation, there are two factors that the programmer must consider to ensure the validity of the output measurement data. The first factor is the time that it takes the Power Meter to respond to a full scale change in input power level. A typical Power Meter response curve is shown in Figure 3-4. By comparing this curve with the measurement timing cycle shown in Figure 3-5 and summarized in Table 3-5, the validity of the Power Meter output can be tabulated according to operating range and triggering interval versus change in input power level. A general summary of this information is as follows:

a. When the Power Meter is programmed for trigger with settling time operation, sufficient time is provided for the Power Meter to settle to the input power level on all ranges except Range 1 (most sensitive range). On Range 1 approximately 10 seconds (9—10 measurements) are required for the Power Meter to settle to the input power level.

b. When the Power Meter is programmed for trigger immediate operation, the desired amount of settling time can be incorporated into the program.

3-31. Programming the Local to Remote Mode Change. The second factor that must be considered when programming the Power Meter for synchronous triggered operation is whether the first trigger is sent immediately after terminating local operation. As illustrated in Figure 3-6, the Power Meter will not respond to the first trigger following a local to remote transistion until it completes the previously initiated measurement and display cycle. Thus, the first data output of the Power Meter may not be valid. The options available to the programmer are:

1. Send a trigger command (Data Message) and discount the first data output. Upon outputting the data, the Power Meter will go to Hold and operate synchronously starting with the next trigger command.
2. Wait approximately 2.5 seconds after placing the Power Meter in remote and sending the first program trigger command (Data Message).
3. Send a Clear Message (DCL) immediately after placing the Power Meter in remote. This will restart the Power Meter operating program.

3-32. Sending Data Messages from the Power Meter

3-33. The (24) TALK ONLY/NORMAL switch (see Figure 3-3) enables the Power Meter to func-

EXAMPLE 2 (Auto Zero)

1	Remove RF power from power sensor (or set it at least 20 dB below the lowest range of the sensor).	
2	{controller talk and Power Meter listen}, **"Z1T"**	Send zero trigger program codes.
3	{universal unlisten, controller listen and Power Meter talk} ,{ variable name}	Read measured value data from meter (characters 4, 5, 6, and 7).
4	If absolute value of measured data is not < 2 (0000 ± 0002) then branch to step 2; if it is, then continue. (Although this step averages three seconds, it may take as long as 10 seconds to execute.)	
5	{controller talk and Power Meter listen} , **"9 + DI"**	Send normal measurement mode program codes.
6	{universal unlisten, controller listen and Power Meter talk} ,{variable name}	Read status character (number 0) from meter's output data string.
7	Check status character for an auto zero loop enabled condition (character 0 ⩾ decimal 84). If loop is enabled then branch to step 5. If not, then continue. (This step takes approximately four seconds to execute.)	

Sending Data Messages (cont'd)

tion as a basic talker or in the talk only mode. If the basic talker function is selected, the Power Meter is configured to talk when the controller places the interface bus in the command mode and outputs talk address M. The Power Meter then remains configured to talk (output data when the interface bus is in the data mode), until it is unaddressed to talk by the controller. To unaddress the Power Meter, the controller can either send an Abort Message (generate an interface clear), or it can place the interface bus in the command mode and output a new talk address or a universal untalk command. Examples of addressing and unaddressing the Power Meter to talk are provided in Table 3-2 and Figure 3-8.

3-34. Talk Only Mode. When the Power Meter functions in the Talk Only Mode, it is automatically configured to TALK when the interface bus is in the Data Mode and there is at least one listener. Since there can only be one talker at a time per interface bus, this function is normally selected only when there is no controller connected to the system (e.g., when the Power Meter is interconnected to an HP 5150A recorder).

3-35. Output Data Format. The output data format of the Power Meter is shown and described in Table 3-4.

3-36. The output data is a fourteen character string that is provided once at the end of each measurement cycle. It is a good idea to read at least part of this string into the controller after each measurement cycle, even if it will not be used. This will avoid the possibility of incorrect data being read after some future measurement.

3-37. The string begins with a status character and ends with a carriage return and a line feed. Measured value is formatted as a real constant: plus or minus four digits (leading zeros not suppressed) followed by an exponential multiplier. The decimal point is not provided because it is understood that it follows the four "measured value" digits. The two-digit exponent is always negative.

3-38. Data Output Time. Figure 3-6 provides a simplified flow chart of Power Meter operation. As shown in the figure, the Power Meter operates according to a stored program and can only output

Table 3-4. Hewlett-Packard Interface Bus Output Data String

	Definition		Character ASC II	Character Decimal
STATUS	Measured value valid		P	80
	Watts Mode under Range		Q	81
	Over Range		R	82
	Under Range dBm or dB [REL] Mode		S	83
	Power Sensor Auto Zero Loop Enabled; Range 1 Under Range (normal for auto zeroing on Range 1)		T	84
	Power Sensor Auto Zero Loop Enabled; Not Range 1, Under Range (normal for auto zeroing on Range 2-5)		U	85
	Power Sensor Auto Zero Loop Enabled; Over Range (error condition — RF power applied to Power Sensor; should not be)		V	86
RANGE	Most Sensitive	1	I	73
		2	J	74
		3	K	75
		4	L	76
	Least Sensitive	5	M	77
MODE	Watt		A	65
	dB REL		B	66
	dB REF (switch pressed)		C	67
	dBm		D	68
SIGN	space (+)		SP	32
	— (minus)		—	45
DIGIT	0		0	48
	1		1	49
	2		2	50
	3		3	51
	4		4	42
	5		5	53
	6		6	54
	7		7	55
	8		8	56
	9		9	57

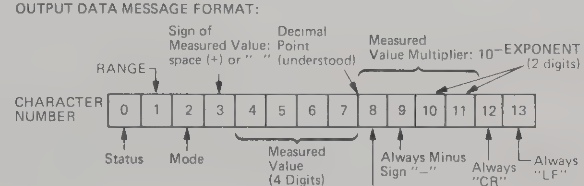


Table 3-5. Power Meter Remote Access Time to First Output Data Character

Measurement Triggering	Mode	Worst Case Access Time to First Output Character		
		Range 1 or 2	Range 3,4 or 5	Auto Range
Free Run at maximum rate, Trigger immediately	WATT dBm dB (REL) db [REF]	70 ms 90 ms 160 ms 160 ms	70 ms 90 ms 160 ms 160 ms	Compute measurement times from Figure 3-5 and add measurement time of each range that Power Meter steps through to delay time listed below. From To Delay — From To Delay 1 2 1070 ms — 3 2 1070 ms 2 1 1070 ms — 4 3,5 133 ms 2 3 133 ms — 5 4 133 ms Examples: Starting at block labeled "HOLD" in Figure 3-5 , worst case access time for range 1—3, and range 3—1 changes with WATT MODE selected are: Range 1 70 ms — Range 3 50 ms (33+17) 1—2 Delay 1070 ms — 3—2 Delay 1070 ms Range 2 53 ms — Range 2 33 ms 2—3 Delay 133 ms — 2—1 Delay 1070 ms Range 3 53 ms — Range 1 33 ms 1379 ms — 2256 ms
Free Run with settling time or Trigger with settling time.	WATT dBm dB (REL) db [REF]	1130 ms 1130 ms 1200 ms 160 ms	190 ms 190 ms 260 ms 160 ms	Compute worst case Auto Range access times from Figure 3-5. Examples: Starting at block labeled "HOLD" in Figure 3-5; worst case access times for range 1-3 and range 3-1 with WATT MODE selected are: 1 - 3 (1070 + 53, +1070 + 53 + 133 + 53) =2432 ms 3-1(133+33+1070+33+1070+33) = 2372 ms.

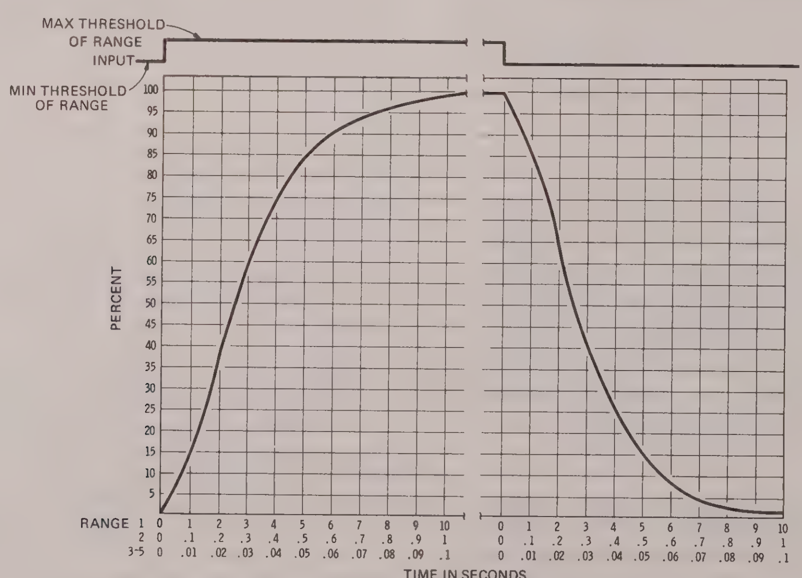


Figure 3-4. Power Meter Response Curve (Settling Time for Analog Circuits)

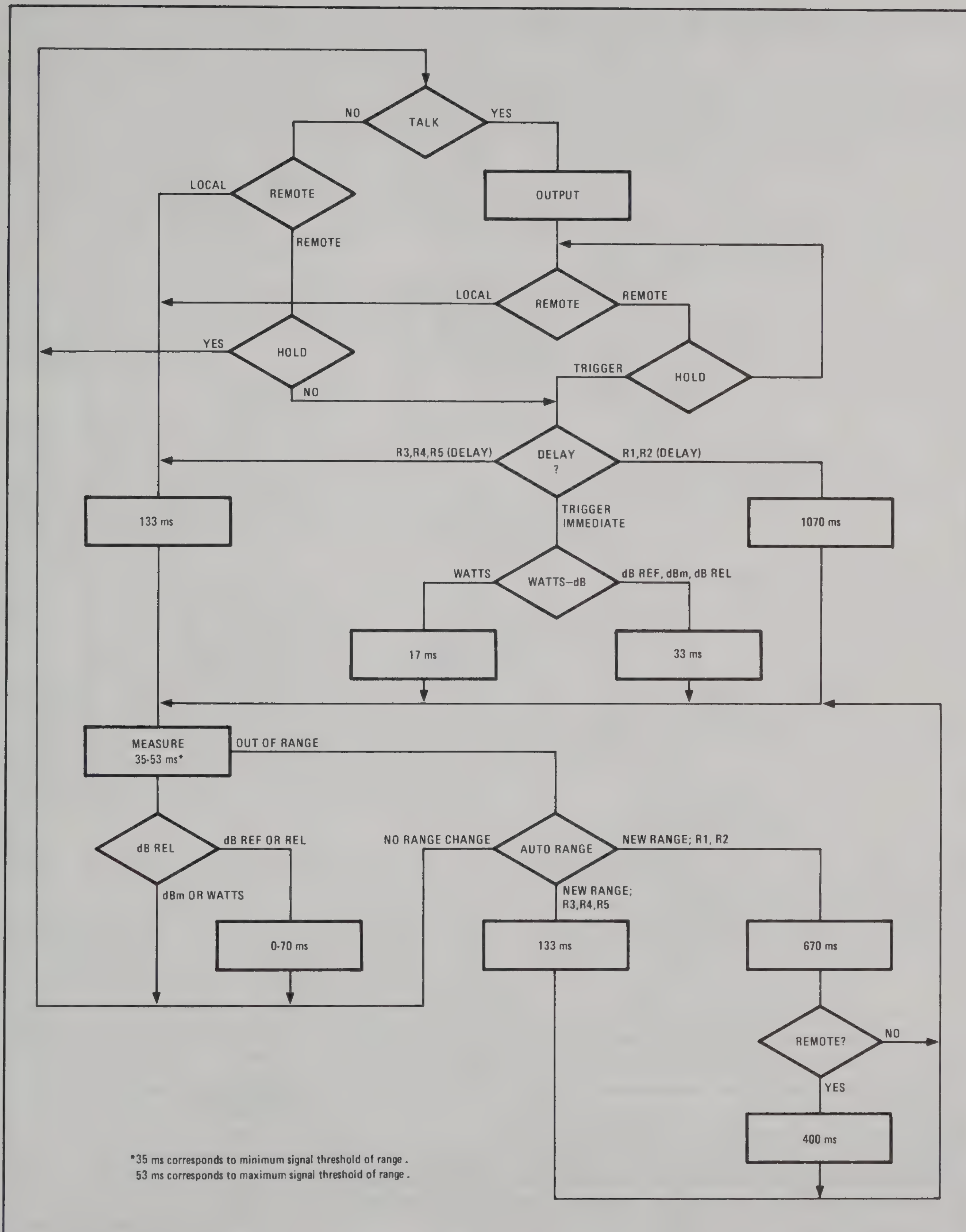
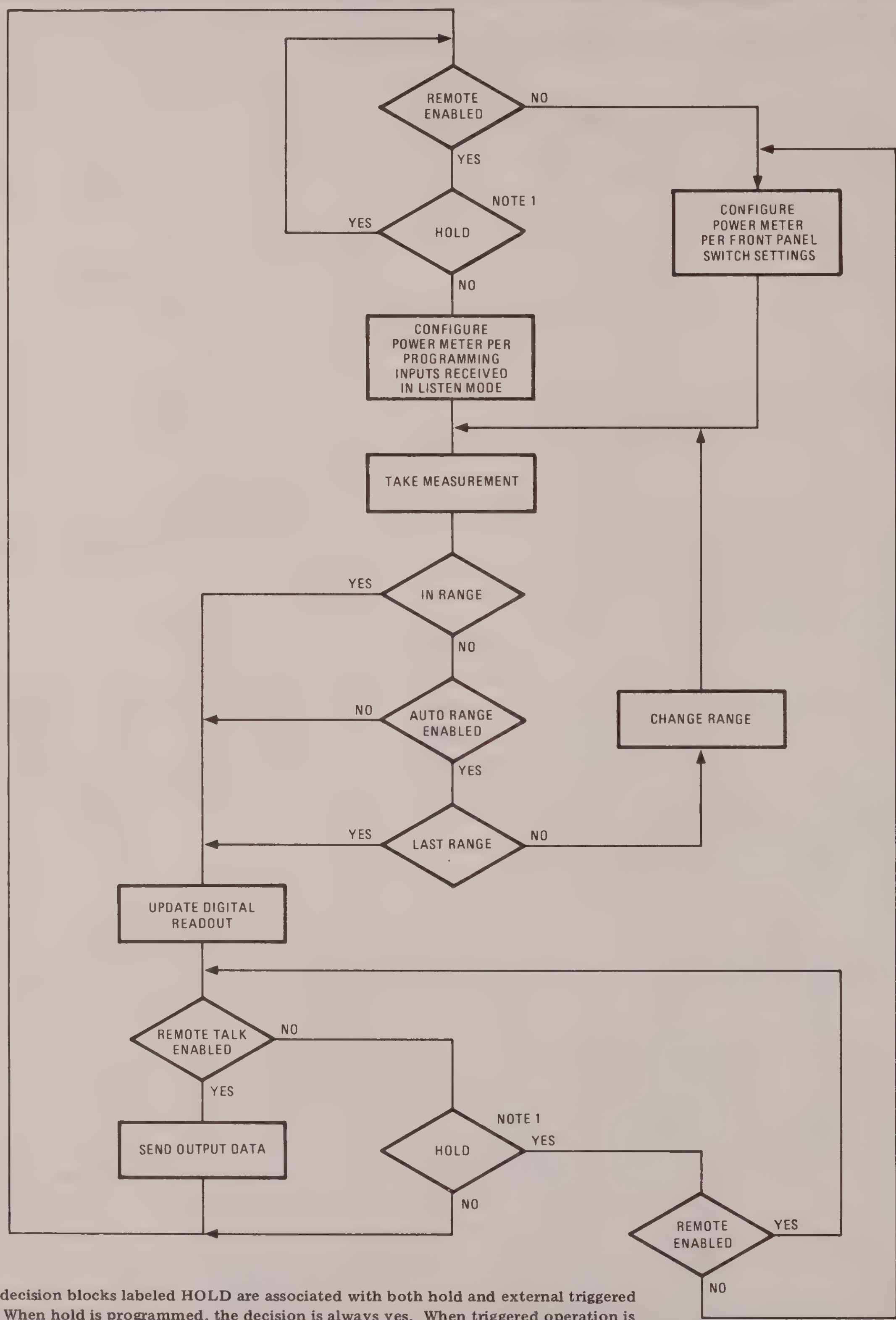


Figure 3-5. Measurement Timing Flow Chart (Settling Time for Digital Circuitry)



Note: The decision blocks labeled HOLD are associated with both hold and external triggered operation. When hold is programmed, the decision is always yes. When triggered operation is programmed, the decision is no, starting when a trigger is received and continuing unitl the digital readout is updated. The decision then reverts to yes until receipt of the next trigger. Thus, when the Power Meter is programmed for external triggering, it will provide output data only after receiving a trigger in the listen mode.

Figure 3-6. Operating Program Simplified Flow Chart

Sending Data Messages (cont'd)

data after taking a measurement. Thus, when the interface bus is placed in the data mode after the Power Meter has been addressed to talk, the time required to access the first output data character depends on where the Power Meter is in the operating program, and on how the Power Meter has been previously programmed (see Programming Codes above.) Worst case access times for each of the Power Meter operating configurations are listed in Table 3-5.

3-39. After the first output character is sent, the remaining characters are sent at either a 10-kHz rate (infinitely fast listener) or at the receive rate of the slowest listener.

3-40. Receiving the Trigger Message

3-41. The Power Meter has no provision for responding to a Trigger Message (bus command GET). Power Meter triggering is done with the Data Message (through the Measurement Rate Program Codes).

3-42. Receiving the Clear Message

3-43. The Power Meter has provision for responding to the DCL bus command but not the SDC bus command. Upon receipt of the DCL command, the Power Meter operating program is reset causing the Power Meter to enter the Hold state shown at the top of Figure 3-6, and the HP-IB circuits are configured to provide Watt Mode, Auto Range, and Cal Factor Disable outputs.

3-44. Receiving the Remote Message

3-45. When the Power Meter recieves the Remote Message (REN line low) it completes the rest of its current measurement cycle (see Figure 3-6) and then goes to remote. See the Local to Remote Mode Change (paragraph 3-31) for information about how to program the local to remote mode change.

3-46. Receiving the Local Message

3-47. The Power Meter does not respond to the GTL (go to local) bus command. It reverts to local operation when the REN (remote enable) bus line goes false (high).

3-48. Receiving the Local Lockout and Clear Lockout Set Local Messages

3-49. The Power Meter does not respond to the Local Lockout Message (LLO bus command). It responds to the Clear Lockout/Set Local Message in that when the REN bus line goes false, it will revert to local operation.

3-50. Receiving the Pass Control Message

3-51. The Power Meter has no provision for operation as a controller.

3-52. Sending the Required Service Message

3-53. The Power Meter does not have provision for requesting service.

3-54. Sending the Status Byte Message

3-55. The Power Meter does not respond to a Serial Poll.

3-56. Sending the Status Bit Message

3-57. The Power Meter does not respond to a Parallel Poll.

3-58. Receiving the Abort Message

3-59. When the Power Meter receives an Interface Clear command (IFC), it stops talking or listening.

3-60. Test of HP-IB Operation

3-61. Figure 3-7 outlines a quick check of the 436A remote functions. This gives the user two alternatives for testing the power meter: 1, write a program corresponding to Figure 3-7 for a quick check or 2, use the program in Section VIII for complete testing and troubleshooting.

3-62. POWER MEASUREMENT ACCURACY

3-63. A power measurement is never free from error or uncertainty. Any RF system has RF losses, mismatch losses, mismatch uncertainty, instrumentation uncertainty and calibration uncertainty. Measurement errors as high as 50% are not only possible, they are highly likely unless the error sources are understood and, as much as possible, eliminated.

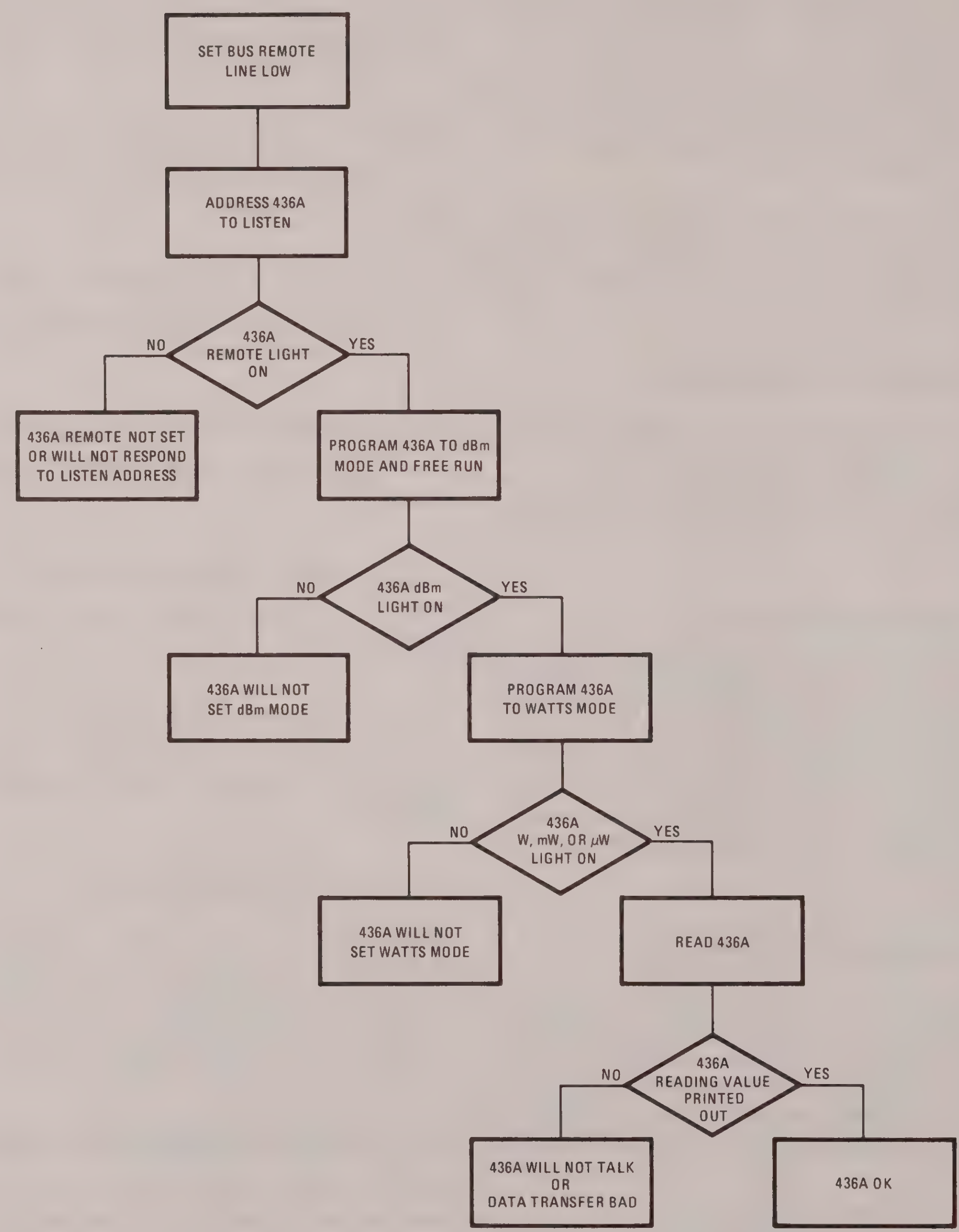
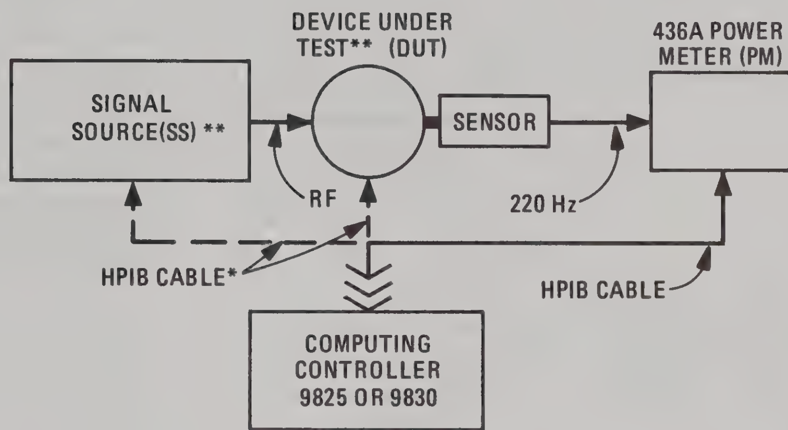


Figure 3-7. Test of HP-IB Operation Flowchart

436A QUICK PROGRAMMING GUIDE

This guide will help set up and program simple HP-IB instrumentation systems, thereby freeing you from making an in-depth study of system design and BASIC or HPL programming languages.

I. THE SYSTEM:



* HP-IB cables shown with dotted lines are used only if the Source and Device under test are programmable.

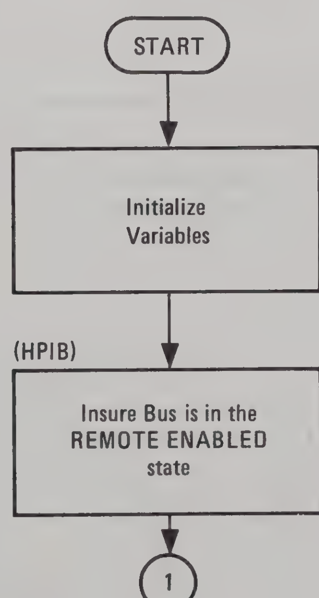
** Signal Source and Device Under Test may be the same, e.g., checking Sig. Gen. Flatness.

II. THE PROGRAM: If the power meter is the only part of the system to be programmed, use the program statements in the order given. For more complex systems or programs, include statements derived from the information in the optional (dashed line) flow chart boxes. When it is necessary to write more statements, refer to Table 3-2.

9830 STATEMENTS (BASIC)

```
10 DIM M[20]
```

```
20 CMD "?U"
30 FORMAT B
40 OUTPUT (13,30)768;
```



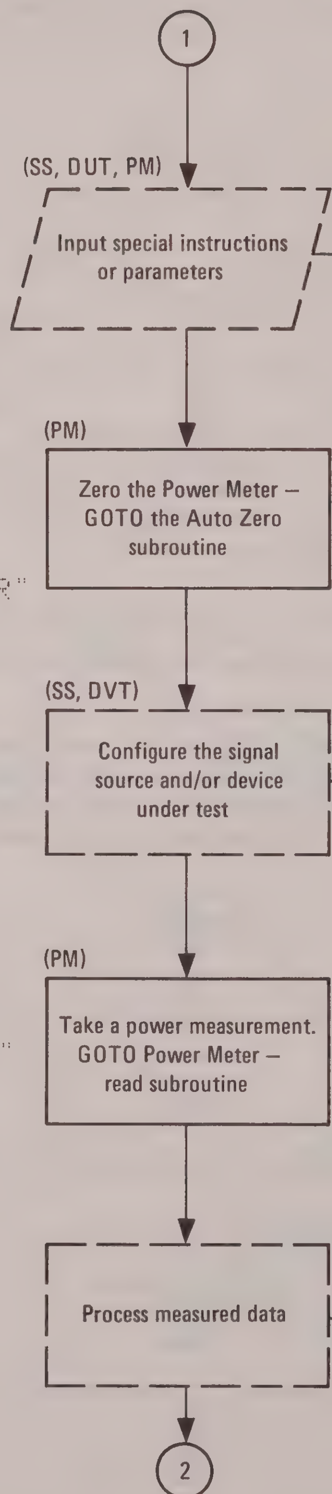
9825 STATEMENTS (HPL)

```
dim M[20]
dev "pmrd",713
```

```
rem 7
```

Figure 3-8. 436A Quick Programming Guide (1 of 5)

436A QUICK PROGRAMMING GUIDE (Cont'd)



9830 STATEMENTS (BASIC)

```
100 REM ZERO PWR METER
110 GOSUB 800
120 DISP "ZERO DONE"
130 WAIT 1000
140 DISP "CONNECT SENSOR"
150 STOP
```

NOTE

See subroutine listing on page 3-35. Insert the subroutines where shown just before the END statement.

```
200 REM READ PWR METER
210 GOSUB 1000
220 DISP "READING TAKEN"
230 WAIT 1000
```

NOTE

See subroutine listing on page 3-35. Insert the subroutine where shown just before the END statement.

9825 STATEMENTS (HPL)

It may be necessary or desirable to specify frequencies, levels, ranges, etc., each time the program is run. Otherwise these parameters are included in the applicable program statements. Refer to the controller operating and programming manual.

```
"zero":cll'pmz';dsp
"zero done";wait 1000
dsp "connect sensor"
;stp
```

NOTE

See subroutine listing on page 3-34. Insert the subroutines where shown just before the END statement.

If the source and/or device under test are programmable, refer to the operating and programming manual. If not, it might be a good idea to have the program stop at this point to allow manual configuration.

```
"gsb readpower";cll
'pmr';dsp "reading
taken";wait 1000
```

NOTE

See subroutine listing on page 3-34. Insert the subroutines where shown just before the END statement.

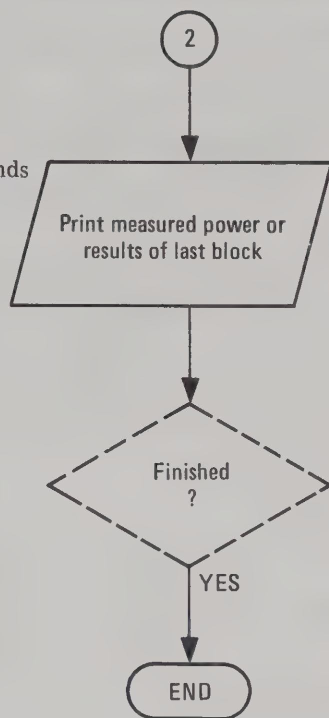
You may want to compare measurements against a reference standard, compute percent error, graph the pwr-freq. curve, or print a table of results, etc. Refer to the controller operating and programming manual.

Figure 3-8. 436A Quick Programming Guide (2 of 5)

436A QUICK PROGRAMMING GUIDE (cont'd)

9830 STATEMENTS (BASIC)

```
300 PRINT M[X]
310 GOTO 9999
```
(optional, depends on next block)



9825 STATEMENTS (HPL)

```
prt M[X]
gto "end"
```
(optional, depends on next block)

Include a GOTO or IF-THEN statement to branch to the appropriate program line. Refer to the controller operating and programmming manual.

Zero subroutine
read subroutine

```
9999 END
```

Zero subroutine
read subroutine

```
"end":end
```

NOTE:

When running the program press CONT–EXECUTE to restart program execution after a STOP (stp) statement.

Figure 3-8. 436A Quick Programming Guide (3 of 5)

436A QUICK PROGRAMMING GUIDE (cont'd)

Subroutines for 9825 (HPL)

"pmz" — Power meter zero subroutine

```
"pmz":
"remove source":dsp "disconnect sensor from source";stp
wrt "pmrd","Z1T";fmt 2,3x,f5.0;red "pmrd.2",Z
"verify zero":if abs(Z)>2;gto "-1"
"unzero":wrt "pmrd","9+AI";fmt 3,b;red "pmrd.3",Z
"verify unzero": if Z>84;gto "unzero"
"preset/ret":wrt "pmrd","9D+V";ret
```

"pmr" — Power meter read subroutine

```
"pmr":
fmt 1,1x,b,1x,f5.0,1x,f3.0
0→R
for X=1 to 20
wrt "pmrd", "9D+V"
wait (R=73)4000
red "pmrd.1",R,P,E
if X=1;gto "P1"
if abs(P-S)>1;gto "P1"
P10^E→P;ret
"P1":P→S
next X
dsp "power meter not settled"
```

Note: *The next statement should be* `"end":end` *, or if another subroutine follows then a* `gto "end"` *should be used.*

Figure 3-8. 436A Quick Programming Guide (4 of 5)

436A QUICK PROGRAMMING GUIDE (cont'd)

Subroutines for 9830 (BASIC)

POWER METER ZERO SUBROUTINE

```
800 REM POWER METER ZERO SUBROUTINE
805 DISP "DISCONNECT SENSOR FROM SOURCE"
806 STOP
810 REM ZERO POWER METER
820 CMD "?U-","Z1T"
830 FORMAT 3X,F5.0
840 CMD "?M5"
850 ENTER (13,830)Z
860 REM TEST FOR ZERO
870 IF ABS(Z)>2 THEN 810
880 REM UNZERO POWER METER
890 CMD "?U-","9+AI"
900 FORMAT B
910 CMD "?M5"
920 ENTER (13,900)Z
930 REM TEST FOR UNZERO
940 IF Z >= 84 THEN 890
950 REM PRESET POWER METER
960 CMD "?U-","9D+V"
970 RETURN
```

POWER METER READ SUBROUTINE

```
1000 REM POWER METER READ SUBROUTINE
1010 FORMAT X,B,X,F5.0,X,F3.0
1020 R=0
1030 FOR X=1 TO 20
1040 CMD "?U-","9D+V"
1050 WAIT (R=73)*4000
1060 CMD "?M5"
1070 ENTER (13,1010)R,P,E
1080 IF X=1 THEN 1120
1090 IF ABS(P-P1)>1 THEN 1120
1100 P=P*10↑(E)
1110 RETURN
1120 P1=P
1130 NEXT X
1140 DISP "POWER METER NOT SETTLED"
```

Note: *The next statement should be* END , *or if another subroutine follows then a* GOTO 9999 *should be used.*

Figure 3-8. 436A Quick Programming Guide (5 of 5)

3-64. Sources of Error and Measurement Uncertainty

3-65. RF Losses. Some of the RF power that enters the Power Sensor is not dissipated in the power sensing elements. This RF loss is caused by dissipation in the walls of waveguide power sensors, in the center conductor of coaxial power sensors, in the dielectric of capacitors, connections within the sensor, and radiation losses.

3-66. Mismatch. The result of mismatched impedances between the device under test and the power sensor is that some of the power fed to the sensor is reflected before it is dissipated in the load. Mismatches affect the measurement in two ways. First, the initial reflection is a simple loss and is called mismatch loss. Second, the power reflected from the sensor mismatch travels back up the transmission line until it reaches the source. There, most of it is dissipated in the source impedance, but some of its re-reflected by the source mismatch. The re-reflected power returns to the power sensor and adds to, or subtracts from, the incident power. For all practical purposes, the effect the re-reflected power has upon the power measurement is unpredictable. This effect is called mismatch uncertainty.

3-67. Instrumentation Uncertainty. Instrumentation uncertainty describes the ability of the metering circuits to accurately measure the dc output from the Power Sensor's power sensing device. In the Power Meter this error is ± 0.5% for Ranges 1 through 5. It is important to realize, however, that these uncertainty specifications do not indicate overall measurement accuracy.

3-68. Power Reference Uncertainty. The output level of the Power Reference Oscillator is factory set to 1 mW ± 0.70% at 50 MHz. This reference is normally used to calibrate the system, and is, therefore, a part of the system's total measurement uncertainty.

3-69. Cal Factor Switch Resolution Error. The resolution of the CAL FACTOR % switch contributes a significant error to the total measurement because the switch has 1% steps. The maximum error possible in each position is ±0.5%.

3-70. Corrections for Error

3-71. The two correction factors basic to power meters are calibration factor and effective efficiency. Effective efficiency is the correction factor for RF losses within the Power Sensor. Calibration factor takes into account the effective efficiency and mismatch losses.

3-72. Calibration factor is expressed as a percentage with 100% meaning the power sensor has no losses. Normally the calibration factor will be 100% at 50 MHz, the operating frequency of the internal reference oscillator.

3-73. The Power Sensors used with the Power Meter have individually calibrated calibration factor curves placed on their covers. To correct for RF and mismatch losses, simply find the Power Sensor's calibration factor at the measurement frequency from the curve or the table that is supplied with the Power Sensor and set the CAL FACTOR % switch to this value. The measurement error due to this error is now minimized.

3-74. The CAL FACTOR % switch resolution error of ±0.5% may be reduced by one of the following methods:

a. Leave the CAL FACTOR % switch on 100% after calibration, then make the measurement and record the reading. Use the reflection coefficient, magnitude and phase angle from the table supplied with the Power Sensor to calculate the corrected power level.

b. Set the CAL FACTOR % switch to the nearest position above and below the correction factor given on the table. Interpolating between the power levels measured provides the corrected power level.

3-75. Calculating Total Uncertainty

3-76. Certain errors in calculating the total measurement uncertainty have been ignored in this discussion because they are beyond the scope of this manual. Application Note AN-64, "*Microwave Power Measurement*", delves deeper into the calculation of power measurement uncertainties. It is available, on request, from your nearest HP office.

3-77. Known Uncertainties. The known uncertainties which account for part of the total power measurement uncertainty are:

a. Instrumentation uncertainty ±0.5% or ±0.02 dB (Range 1 through 5).

b. Power reference uncertainty ±0.7% or ±0.03 dB.

3-77. Known Uncertainties (cont'd)

c. CAL FACTOR switch resolution ±0.5% or ±0.02 dB.

The total uncertainty from these sources is ±1.7% or ±0.07 dB.

3-78. Calculating Mismatch Uncertainty. Mismatch uncertainty is the result of the source mismatch interacting with the Power Sensor mismatch. The magnitude of uncertainty is related to the magnitudes of the source and Power Sensor reflection coefficients, which can be calculated from SWR. Figure 3-9 shows how the calculations are to be made and Figure 3-10 illustrates mismatch uncertainty and total calculated uncertainty for two cases. In the first case, the Power Sensor's SWR = 1.5, and in the second case, the Power Sensor's SWR = 1.26. In both cases the source has a SWR of 2.0. The example shows the effect on power measurement accuracy a poorly matched power sensor will have as compared to one with low mismatch.

3-79. A faster, easier way to find mismatch uncertainty is to use the HP Mismatch Error (uncertainty) Limits/Reflectometer Calculator. The calculator may be obtained, on request, from your nearest Hewlett-Packard office by using HP Part Number 5952-0448.

3-80. The method of calculating measurement uncertainty from the uncertainty in dB is shown by Figure 3-11. This method would be used when the initial uncertainty calculations were made with the Mismatch Error/Reflectometer Calculator.

CALCULATING MEASUREMENT UNCERTAINTY

1. Calculate the reflection coefficient from the given SWR.

$$\rho = \frac{SWR - 1}{SWR + 1}$$

Power Sensor #1	Power Sensor #2	Power Source
$\rho_1 = \frac{1.5 - 1}{1.5 + 1}$	$\rho_2 = \frac{1.25 - 1}{1.25 + 1}$	$\rho_s = \frac{2.0 - 1}{2.0 + 1}$
$= \frac{0.5}{2.5}$	$= \frac{0.25}{2.25}$	$= \frac{1.0}{3.0}$
$= 0.2$	$= 0.111$	$= 0.333$

2. Calculate the relative power and percentage power mismatch uncertainties from the reflection coefficients. An initial reference level of 1 is assumed.

Relative Power Uncertainty

$$PU = [1 \pm (\rho_n \rho_s)]^2 \text{ where } \begin{array}{l} P_n = \text{SWR of Power Sensor \# n} \\ P_s = \text{SWR of Power Source} \end{array}$$

$$\begin{aligned} PU_1 &= \left\{1 \pm [(0.2)(0.333)]\right\}^2 \\ &= \left\{1 \pm 0.067\right\}^2 \\ &= \left\{1.067\right\}^2 \text{ and } \left\{0.933\right\}^2 \\ &= 1.138 \text{ and } 0.870 \end{aligned}$$

$$\begin{aligned} PU_2 &= \left\{1 \pm [(0.111)(0.333)]\right\}^2 \\ &= \left\{1 \pm 0.037\right\}^2 \\ &= \left\{1.037\right\}^2 \text{ and } \left\{0.963\right\}^2 \\ &= 1.073 \text{ and } 0.938 \end{aligned}$$

Percentage Power Uncertainty

$$\%PU = (PU - 1)\ 100\% \text{ for } PU > 1 \quad \text{and} \quad -(1 - PU)\ 100\% \text{ for } PU < 1$$

$$\begin{aligned} \%PU_1 &= (1.138 - 1)\ 100\% && \text{and} && -(1 - 0.870)\ 100\% \\ &= (0.138)\ 100\% && \text{and} && -(0.130)\ 100\% \\ &= 13.8\% && \text{and} && -13.0\% \end{aligned}$$

$$\begin{aligned} \%PU_2 &= (1.073 - 1)\ 100\% && \text{and} && -(1 - 0.928)\ 100\% \\ &= (0.073)\ 100\% && \text{and} && -(0.072)\ 100\% \\ &= 7.3\% && \text{and} && -7.2\% \end{aligned}$$

Figure 3-9. Calculating Measurement Uncertainties (1 of 2)

CALCULATING MEASUREMENT UNCERTAINTY

3. Calculate the Measurement Uncertainty in dB.

$$MU = 10\left[\log_{10}\left(\frac{P_1}{P_0}\right)\right] \text{ dB for } \frac{P_1}{P_0} > 1$$

$$= 10\left[\log\left(\frac{10P_1}{10P_0}\right)\right] \text{ dB}$$

$$= 10\ [\log(10P_1) - \log(10P_0)] \text{ dB for } \frac{P_1}{P_0} < 1$$

MU_1	$= 10\left[\log\left(\frac{1.138}{1}\right)\right]$	and	$10\ [\log(10)(0.870) - \log(10)(1)]$
	$= 10\ [0.056]$	and	$10\ [\log(8.70) - \log(10)]$
		and	$10\ [0.94 - 1]$
		and	$10\ [-0.060]$
	$= +0.56$ dB	and	-0.60 dB
MU_2	$= 10\left[\log\left(\frac{1.073}{1}\right)\right]$	and	$10\ [\log(10)(0.928) - \log(10)(1)]$
	$= 10\ [0.031]$	and	$10\ [\log(9.28) - \log(10)]$
		and	$10\ [0.968 - 1]$
		and	$10\ [-0.032]$
	$= +0.31$ dB	and	-0.32 dB

Figure 3-9. Calculating Measurement Uncertainties (2 of 2)

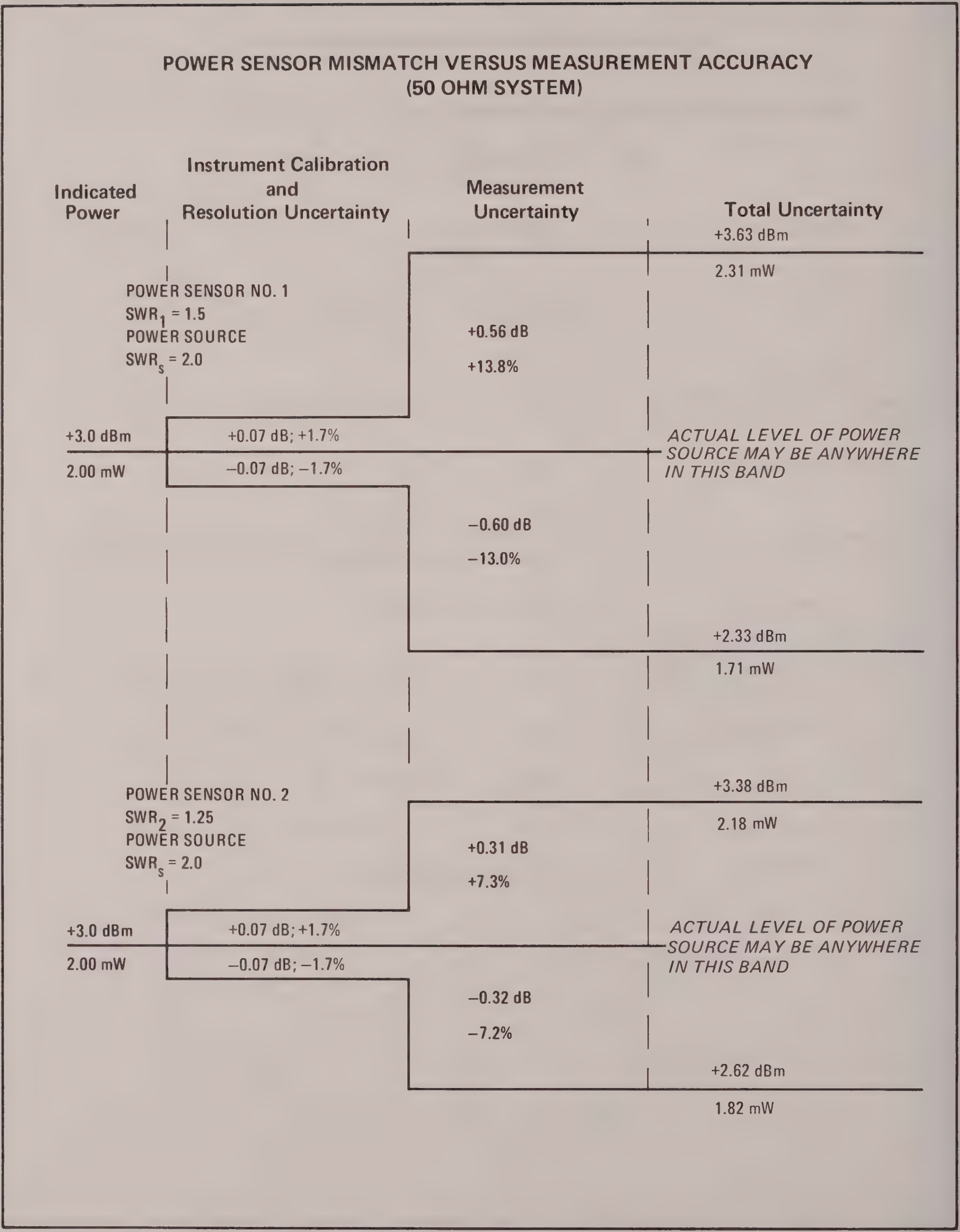


Figure 3-10. The Effect of Power Sensor Mismatch on Measurement Accuracy

CALCULATING MEASUREMENT UNCERTAINTY

1. For this example the known values are: source SWR, 2.2 and power sensor SWR, 1.16. From the Mismatch Error Calculator the mismatch uncertainty is found to be +0.24, −0.25 dB.

2. Add the known uncertainties from paragraph 3-73, (± 0.10 dB). Our total measurement uncertainty is +0.34, −0.35 dB.

3. Calculate the relative measurement uncertainty from the following formula:

$$dB = 10 \log \left(\frac{P_1}{P_0}\right)$$

$$\frac{dB}{10} = \log \left(\frac{P_1}{P_0}\right)$$

$$\frac{P_1}{P_0} = \log^{-1} \left(\frac{dB}{10}\right)$$

If dB is positive then:
$P_1 > P_0$; let $P_0 = 1$

$$MU = P_1 = \log^{-1}\left(\frac{dB}{10}\right) = \log^{-1}\left(\frac{0.34}{10}\right) = 1.081$$

If dB is negative then:
$P_1 < P_0$; let $P_1 = 1$

$$MU = P_0 = \frac{1}{\log^{-1}\left(\frac{dB}{10}\right)} = \frac{1}{\log^{-1}\left(\frac{0.35}{10}\right)} = \frac{1}{1.082} = 0.923$$

4. Calculate the percentage Measurement Uncertainty.

For $P_1 > P_0$

$$\%MU = (P_1 - P_0)\,100 = (1.081 - 1)\,100 = +8.1\%$$

For $P_1 < P_0$

$$\%MU = -(P_1 - P_0)\,100 = -(1 - 0.923)\,100 = -7.7\%$$

Figure 3-11. Calculating Measurement Uncertainty (Uncertainty in dB Known)

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